5.0 IN-RIVER DISTRIBUTION OF ~~INDICATOR CHEMICALS~~CONTAMINATION

This section discusses ~~T~~the distribution of ~~ICs~~ contamination in the river environment ~~in sediment, in-river sediment traps, surface water, TZW and groundwater seeps, and biota is summarized in this section~~.[1,2] Section 5.1 discusses how certain contaminants were selected for discussion and use in the RI. The following sections are organized by media and focus on the in-river contaminant distribution in and immediately adjacent to the Study Area, as well as upriver and downriver of the Study Area. Section 5.2 discusses the in-river distribution of contaminants in bedded sediments (surface and subsurface), Section 5.3 discusses mobile sediment (as measured in sediment traps or borrow pits), Section 5.4 discusses the in-river distribution of contaminants in surface water, Section 5.5 discusses the distribution of contaminants in transision zone water and groundwater seeps, and Section 5.6 discusses the distribution of contaminants in biota tissue.

Commented [A1]: This list is of media and sediment traps are not a media. While the descriptor has changed, the discussion will still discuss the sediment trap data.

The discussions in the following subsections will focus on distribution of contamination as orders of magnitude of detected values (e.g., <1, 1-10, 10-100, 100-1,000, etc.). Depending on the medium examined, the discussion of contaminant distribution is supported by a variety of tabular and graphical materials: 1) maps showing the extent of each contaminant's distribution, 2) summary statistics tables, 3) scatter-plot graphs depicting chemical concentrations by river mile, and 4) ~~bar charts~~histogram and box-whisker plots for comparing values and distributions.

For each of the following subsections, summary statistics tables present the frequency of detection, the minimum, maximum, mean, median, and 95th percentile, and the station locations of the maximum values. The tables also present statistics with only detected values and and statistics with combined detect and nondetect values. The statistics have been compiled separately for the RI Study Area reach (RM 1.9–11.8), exclusive of the Multnomah Channel), the downtown reach (RM 11.8-15.3), the upriver reach (RM 15.3-26) and the downriver reach (RM 0-1.9) [refer to Map 5.0-1]. Summary statistics for sediments include both point samples and beach composite samples to provide a general understanding of contaminant concentration distributions.

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Where specific sample results are cited in the text (i.e., the concentration of a sample, median and 95th percentile values) qualifiers associated with that result are also cited, with one exception. The qualifier "T" is not cited as it generally indicates that the result was mathematically derived through summing multiple results (e.g., total PCB congeners equal the sum of the PCB congener results). The "T" qualifier may also indicate that a result is an average of multiple results for a single analyte (e.g., field replicates) or that a result was selected for reporting in preference to other available

[1] The discussion of chemical nature and extent may include use of facility names and landmarks (e.g., bridges) for location references; mention of such names does not necessarily indicate a source or origin.

[2] Section 5 text, maps, figures, and tables are based on the data ~~lockdown date~~as of ~~June 2, 2008. Data collected or received between June 2, 2008 and~~ July 19, 2010 ~~is presented in Appendix H~~.

results (e.g., for parameters reported by multiple methods). The following qualifiers are cited with the results:

> **A** – Total value is based on a limited number of analytes.
>
> **J** – The associated numerical value is an estimated quantity.
>
> **N** – Presumptive evidence of presence of organic compound; identification of the compound is not definitive. The N qualifier is used in combination with the J qualifier.
>
> **U** – The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.

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In certain cases, concentrations of closely related analytes were added together to create a group sum. When calculating group concentrations for this in-river contaminant distribution evaluation, a value of zero was used for non-detected concentrations on an individual sample basis.[3] The 2,3,7,8- TCDD TEQ values for dioxin-like PCB congeners and PCDD/Fs were calculated with WHO 2005 TEFs for mammals[4] (Van den Berg et al. 2006). The bezo(a)pyrene equivant (BaPEq) values used to represent carcinogenic PAHs (cPAHs) were calculated using PEFs provided in EPA (1993). Tables in Appendix D1.6 present the constituent concentrations used in each group sum. Further information on summing methods is provided in Appendix A.—

Commented [A2]: Nature and extent refers to the source from which the release occurs to the areal extent of that release in the environment. This section is not discussing nature and extent, but only in-river distribution of contamination.

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5.1 SELECTION OF INDICATOR CONTAMINANTS

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Contaminants of interest (COIs) are contaminants expected to be present at a site based on a review of site information. Numerous chemical ~~and physical~~ parameters were identified ~~as COIs~~ for the Study Area from the site assessment and were subsequently analyzed and detected in sampled various media ~~(Table 5.0-1)~~. Summary statistics for all COIs are presented by media for each river reach in Appendix D. ~~Owing to the distribution of contaminant sources and the dynamic nature of the Willamette River, COIs have become comingled to some extent throughout the Study Area.~~ Table 5.1-1 presents the COIs detected in the various media (sediment, water and biota) of the river.

Commented [A3]: Table 5.0-1 does not accurately present COIs that were detected nor all media sampled. Incorporate EPA Table 5.1-1.

Commented [A4]: This is a conclusion statement: Conclusions are discussed in Section 10.

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Due to the large number of COIs detected at the site in various media, this section of the RI will focus on a subset of the contaminants (indicator contaminants) ~~T~~to facilitate a clear and practical presentation of the ~~nature and~~ distribution of contamination in the Study Area for the RI.~~,~~ It should be noted that additional contaminants beyond the indicator contaminants presented in this section are present at the site that pose unacceptable risk to human health and the environment and by limiting the

---

[3] Using zero for non-detects in summing prevents high detection limits from creating confusion in the evaluation of in-river distribution.

[4] The World Health Organization (WHO) has provided a list of 12 dioxin-like congeners which are PCB-77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189.

~~This draft document has been provided to EPA at EPA's request to facilitate EPA's comment process on the document in order for LWG to finalize the RI. The comments or changes (including redlines) on this document may not reflect LWG positions or the final resolution of the EPA comments.~~

contaminants in this section in no way limits the contaminants that will be considered in the FS or cleanup decisions made by EPA.~~an IC list~~

Indicator contaminants w~~as~~ere identified using a screening process (Table 5.1-2) that first compared the detected COIs at the site (Table 5.1-1) with those contaminants potentially posing unacceptable risk to human health and the environment ~~(Table 5.1-2)from the extensive list of COIs to represent the nature and extent of the range of contaminants that potentially pose risk to human health and the environment in sediment, surface water, TZW, and biota. Although additional COIs beyond the IC list may pose risk to human health and the environment and are present within the Study Area, the IC list was generated, in consultation with EPA[5] in the spring/summer of 2008, based on the chemicals that emerged from the Round 2 risk screening and preliminary risk evaluation process~~ and then consider~~ation of~~ed the following ~~non-risk-based~~ factors:

Commented [A5]: Appendix A5 has been deleted from the RI.

- Frequency of detection—~~Chemicals~~Contaminants (pesticides) with a ~~high~~ frequency of detection >20% ~~(e.g., generally >50%)~~were not selected ~~were selected as an IC~~.
- Cross media comparisons—~~Preference was given to chemicals~~Contaminants that would allow comparisons across media were selected.
- Co-location of ~~Representative chemicals~~contaminants—Several ~~ICs~~contaminants were selected to represent ~~a suite of compounds~~other contaminants due to co-location of the contaminants (e.g., ~~BEHP was selected to represent the phthalate group~~arsenic, chromium, copper and zinc were selected to represent other metals).
- Widespread sources – Certain other contaminants with widespread sources in the harbor (e.g., metals, PAHs, and PCBs) were selected.
- Grouped contaminants – Some contaminants were grouped into one contaminant (e.g., PCB aroclors and congeners were gouped into total PCBs). Contaminants that were grouped include PCBs, PCDD/Fs, DDx, and PAHs.
- Low exceedance of risk – Several contaminants had low exceedance of risk (HQ<10 or risk at 10^{-6}) and were not selected.

The first screen indentified 35 key contaminants in the Study Area. An additional screen identified 14 indicator contaminants, which are the focus of further discussion in the RI. Although not discussed further in the RI, summary statistic tables, maps and figures by media are presented in Appendix for the 21 “key contaminants” that were not identified as indicator contaminants.

- ~~EPA requests – EPA requested the inclusion of several additional chemicals for sediment and biota based on its review of the Round 2 Report (Integral et al.~~

~~[5] As documented in Appendix A5, Attachments A4, A7, A9, and A11.~~

~~2007). EPA also requested the inclusion of certain other chemicals with widespread sources in the harbor (metals, PAHs, and TPH) during the IC lists development discussions in 2008.~~

Table 5.1~~0~~-2~~2~~ identifies the ~~ICs~~[6] indicator contaminants selected by this process for ~~various uses~~further discussion in the RI.

Contaminants that were screened due to co-location were based either on one form of a contaminant representing another or on a correlation plot of the rank and location of the data sets. The basis for each contaminant screening due to co-location is presented in Table 5.1-3 and Figures 5.1-1 through 5.1-5~~8~~.

Commented [A6]: These are the new correlation plots.

Data presentations identical to those provided in the following sections are also provided for physical parameters and other key COIs in Appendix D; however, there is no discussion or interpretation of the information.

~~This includes nature and extent for abiotic and biotic media chemicals (Section 5); loading, fate, and transport (Section 6); fate and transport modeling (part of FS); and the site-wide CSM (Section 10).~~

~~Once the baseline risk assessments were completed (the BHHRA is provided in Appendix F; the BERA in Appendix G), a list of contaminants posing potentially unacceptable risk was documented. These contaminants for the BHHRA and BERA are listed in Table 7-1 in Appendix F and Table 11-2 in Appendix G, respectively, and are included in Table 5.0-2. Additionally, chemicals in surface water and TZW sampling results that exceed tap water and surface water quality criteria/screening values (without taking into account any spatial or temporal averaging) are also included in Table 5.0-2; these contaminants will be carried into the FS for evaluation of chemical mobility. The water screening methods and results are provided in Appendix D3.3 and Anchor QEA (2011).~~

~~The nature and extent of four ICs or compound groups identified in the BHHRA and BERA as posing risk in the Study Area are believed to encompass the spatial extent of potentially unacceptable risks associated with the contaminants identified in the baseline risk assessments. These four chemicals, hereafter referred to as bounding ICs, are total PCBs, total PCDD/Fs (as both total dioxins/furans and dioxin/furan TCDD TEQ~~[7]~~), total DDx, and total PAHs. This is not intended to imply that other contaminants will not be evaluated in the FS and accounted for in the site remedy~~[8]~~.~~

[6] ~~Contaminants for which PRGs are being developed through the FS process will not be finalized until late 2011. However, the LWG presumes that the ICs included in the RI will be consistent with the PRG list.~~

[7] ~~The dioxin/furan TCDD TEQ does not include dioxin-like PCB congeners.~~

[8] ~~These four COCs largely represent the areal extent of unacceptable risk to humans and wildlife (birds and mammals). Other COCs are associated with unacceptable risk, but generally within the areas represented by these four COCs. The exception may be where toxicity test results indicate unacceptable risk to the benthic invertebrate community, but no specific chemical has been associated with toxicity.~~

~~Other contaminants potentially posing risk are comingled with the bounding ICs, but because of their spatial distribution within the Study Area, only these bounding chemicals are discussed in detail in the Section 5 subsections that follow. For each medium, the nature and extent of the an additional set of ICs is also described in the following subsections. This set varies by media but it includes all chemicals that are the focus of the comprehensive cross-media and fate and transport evaluations presented in Section 10 (CSM) of this RI. This set of CSM chemicals was selected in consultation with EPA to provide a relatively complete picture of the distribution, transport, and fate of contaminants in the Study Area across a range of physical, chemical, and biological processes, as well as known and potential sources. Finally, tThe nature and extent data for the balance of the ICs COIs listed in Table 5.0-12 are presented on all tables, maps, and figures in Appendix D but not addressed in the narrative.~~

~~The following sections are organized by media and focus on the nature and extent of ICs in and immediately adjacent to the Study Area in sediments (Section 5.1), sediment traps (Section 5.2), surface water (Section 5.3), TZW (Section 5.4), and biota (Section 5.5).~~

Commented [A7]: This paragraph and the following paragraphs were incorporated into Section 5.0 discussion.

~~Depending on the medium examined, the nature and extent discussion is supported by a variety of tabular and graphical materials: 1) plan-view and core maps for sediment showing the extent of each chemical's distribution, 2) summary statistics tables, 3) scatter-plot graphs depicting chemical concentrations by river mile, and 4) bar charts and box-whisker plots for comparing values and distributions. Summary statistics for ICs are tabulated in the main text for bedded sediment (Tables 5.1-1 and 5.1-2), in-rivermobile sediment traps (Tables 5.2-1 through 5.2-4), surface water (Tables 5.3-2 through 5.3-7), and biota (Tables 5.5-1 and 5.5-2). Summary statistics for all parameters analyzed in each medium are presented in tables included in Appendix D. The entire RI database is presented in Appendix A3, and the updated RI database is presented in Appendix H, Attachment H-2.~~

~~For each IC, the following summary statistics are tabulated: the frequency of detection; the minimum, maximum, mean, median, and 95th percentile; and the station locations of the maximum values. Two sets of statistics are presented for each IC. One set reflects only detected values and the other set shows detected and undetected values combined. The statistics have been compiled separately for areas inside the Study Area (RM 1.9–11.8, ≤13 ft NAVD88, exclusive of the Multnomah Channel) and areas outside of it. Summary statistics for sediments include both point samples and composite samples to provide a general understanding of IC concentration distributions. The discussion of the nature and extent of ICs in media provided in the remainder of this section is based on statistics calculated for detected concentrations only.~~

~~Where specific results are cited in the text (i.e., the concentration of a sample, median and 95th percentile values) qualifiers associated with that result are also cited, with one exception. The qualifier "T" is not cited as it generally indicates that the result was mathematically derived through summing multiple results (e.g., total PCB congeners~~

~~equal the sum of the PCB congener results). The "T" qualifier may also indicate that a result is an average of multiple results for a single analyte (e.g., field replicates) or that a result was selected for reporting in preference to other available results (e.g., for parameters reported by multiple methods). The following qualifiers are cited with the results:~~

~~**A** Total value is based on a limited number of analytes.~~

~~**J** The associated numerical value is an estimated quantity.~~

~~**N** Presumptive evidence of presence of material; identification of the compound is not definitive.~~

~~**U** The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.~~

~~**V** Median or 95th percentile was obtained through interpolation of data.~~

~~In certain cases, concentrations of closely related analytes were added together to create a group sum. When calculating group concentrations for this nature and extent evaluation, a value of zero was used for non-detected concentrations on an individual sample basis; other analyte summing approaches were used in the risk evaluations presented in Appendices F and G of this report for the BHHRA and BERA, respectively.[9] The 2,3,7,8- TCDD TEQ values for dioxin-like PCB congeners and PCDD/Fs were calculated with WHO 2005 TEFs for mammals (Van den Berg et al. 2006). The bezo-a-pyrene equivant cPAH (BaPEq) values used to represent carcinogenic PAHs (cPAHs) were calculated using PEFs provided in EPA (1993). Tables in Appendix D1.6 present the constituent concentrations used in each group sum. Further information on summing methods is provided in Section 2.1.4Appendix A.~~

~~5.13~~5.2 INDICATOR ~~CHEMICALS~~ CONTAMINANTS IN BEDDED SEDIMENT

This section summarizes the surface and subsurface sediment data collected in the upriver reach, downtown reach, Study Area reach, and downriver reach. The locations of all surface and subsurface sediment samples in the ~~nature and extent~~RI data set are shown on Maps 2.2-15,~~a-y~~ ~~and~~ 2.1~~-~~.17, ~~and~~ H2.3-1 and H2.3-22~~-2a-t~~. ~~The surface sediment data set includes all samples with intervals starting at 0 cm and extending to~~

Commented [A8]: These were moved to Appendix A...need to update with current figure numbers.

Commented [A9]: Since this sentence discusses the data set, it was moved to 5.2.1.

~~[9] For the RI, the summation methods use zero for non-detects within sums. This allows a clear presentation of detected results for assessment of nature and extent, avoiding bias presented by the detection limits. This also prevents high detection limits from creating confusion in the evaluation of nature and extent. For the BHHRA and BERA, the summation method uses one-half the detection limit for non-detects within the sums. This was the agreement with EPA.~~

~~depths ranging to 40 cm bml.~~[10] The~~ise~~ discussion of each contaminant focuses primarily on the following items:

- A description of the data set for each contaminant, including sample counts, concentration range, and frequency of detection.
- A discussion of the surface and subsurface concentration distributions in the upriver reach, downtown reach, RI Study Area reach, and downriver reach. The RI Study Area reach is organized by eastern nearshore, western nearshore, and navigation channel subareas (Map 5.2-33) and discusses distributions within river mile reaches and hydrodynamic reaches (see discussion in Section 3).
- A discussion of the vertical trends in sediment concentrations and the relationship of subsurface sediment to surface sediment concentrations.

The sediment chemistry distributions are depicted in four graphical formats:

1. S~~s~~urface plan-view concentration maps ~~-~~and subsurface core concentration maps (all reaches)~~ (Maps 5.2-1 through 5.2-28);~~,
2. S~~s~~catter-plot graphs of surface and subsurface sediment (RM 0.8-12.2)~~ (Figures 5.2-1 through 5.2-32);, and~~
3. H~~h~~istograms comparing mean surface and subsurface concentrations by river mile (~~Figures 5.2-33 through 5.2-45~~RM 0-11.8); and
4. Box and whisker plots of surface and subsurface sediment by river reach.

Core plots showing a higher level of detail have been produced for the following indicator contaminants:

- Total PCBs
- Total DDx
- TCDD TEQ
- Total PAHs.

Additionally, more detailed core plots were developed for t~~T~~otal cPAHs and presented in Appendix D1.2. More detailed core plot maps were developed for these particular contaminants because they are more prevalent throughout the Study Area.

~~[10] The functional definition of surface sediments for this site is 0–30 cm based on physical system studies. However, the recorded lower depth of a set of sediment samples (i.e., shallow cores that begin at the mudline) in the nature and extent data set reached to 40 cm. These samples were grouped with the surface data set, thus extending the maximum depth for the surface horizon to 40 cm. Core samples that extended from the mudline to depths greater than 40 cm were grouped with the subsurface sediment data set.~~

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Commented [A10]: Appendix H3 surface maps will replace surface maps in this section.

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Commented [A11]: Appendix D1.2 maps will replace subsurface maps for Total PCBs, Total DDx, TCDD TEQ, Total PAHs, and Total cPAHs. Appendix H3 subsurface maps for each indicator contaminant will be added to end of each series of subsurface maps in Section 5 as "n" and "o".

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Surface Chemistry Maps: The plan-view concentration maps present all surface sample data using color-coded dots that correspond to a concentration scale for that particular chemical. The concentration ranges (or intervals) used in color-coding the chemical data shown on the maps were based on the frequency distributions (i.e., natural breaks) in the data set for these contaminants and has no environmental significance. Non-detected concentrations are differentiated from detected concentrations on the surface maps by a dot in the center of the sample symbol (i.e. ◉). The maps include data points from locations that were dredged or capped subsequent to the collection of the sample(s) (shown by a circle centered around the sample symbol [i.e., ◎]).[11,12] Data from these areas are presented to show spatial patterns of chemicals from a historical, pre-dredge perspective. In addition, the surface maps include histograms showing the distributions and frequencies of the detected and non-detected results. Data from all samples shown on the maps are included in the histograms.

Subsurface Core Maps: The core maps show the distribution of contaminants with depth at each of the subsurface sediment sampling stations (these maps also include the surface sample data). Inset maps for densely sampled core areas are provided in most cases. In these maps, the actual core station is marked with a triangle (i.e., △). The core segment divisions displayed on the maps are scaled to the thickness of each sample interval. Note that these maps do include cores from locations that were subsequently dredged or capped, as indicated on the maps. Cores taken post-dredging are also included on the maps. The subsurface concentration maps do not indicate samples where concentrations are based on partial sums (i.e., A-qualified data; the few cases where data are based on partial sums ~~are~~ from non-LWG studies).

Scatter Plots: Scatter plots present the distribution of detected contaminants in surface and subsurface sediment per river mile. The data are presented in a log scale (by order of magnitude) to facilitate in the discussion on distribution and to fit all the data onto one plot due to the vast range in concentrations detected. To aid in differentiating potential concentration trends in the Study Area, the data in these plots are further separated into eastern nearshore, western nearshore, and navigation channel~~, and Multnomah Channel~~ stations as defined by the federal navigation channel boundary (Map 5.2-33). ~~The areas falling into these categories are shown in Map 5.1-29.~~ Data collected in Multinomah Channel is presented with the western shore data and is identified using a different symbol. Likewise, data collected in Swan Island Lagoon is presented with the eastern shore data and identified with a unique symbol. Unlike the plan-view maps, the scatter plots do *not* include data for samples from locations that have been subsequently dredged or capped.

[11] For example, all data shown for locations *within the capped area* at the M&B site (see Maps 2.2-1i and 2.2-2i) are from surveys completed between 1999 and 2002, prior to capping. These data are shown on the surface and subsurface core plan-view maps and included in the map histograms; however, they are not included in the other sediment data presentations (i.e., scatter plots~~,~~ and histograms~~, and stacked bar charts, discussed below~~).

[12] Surface interval sample locations G088, G087, and G091 collected in 2004 in the International Terminals Slip were dredged subsequent to sampling. These locations were resampled in 2005 at C088, C087, and C091.

Histograms: The histograms compare the average surface and subsurface sediment chemical concentrations for the indicator contaminants on subarea basis (e.g., RM 8-9 west of channel. The y-axis in the plots is centered on a value of 0, which represents the vertical horizon (40 cm bml) between the surface and subsurface samples. Bars extending downward from the y-axis deptict the subsurface mean values. Bars extending upward show the surface sediment means. Subareas included east, navigation channel, and west zones for each river mile in the Study Area, as well as Multnomah Channel, Swan Island Lagoon, downstream reach (RM 0–2), upriver reach (RM 15.3-26), and downtown reach (RM 11.8-15.3). Mean concentrations were also calculated for each zone in the entire Study Area (see leftmost column in each figure).

These histograms are useful in providing a visual summary of spatially averaged surface/subsurface trends throughout the Study Area. However, some caution is needed in interpreting the trends due to the biased nature of the RI sampling program (i.e., subsurface core samples were generally focused on known areas of contamination, whereas surface samples were distributed more widely). Further, highly contaminated areas may not necessarily be contained within a specific river mile, but rather partially overlap two adjacent river miles. Consequently, these histograms should be examined in conjunction with the subsurface core maps in evaluating surface to subsurface trends for a specific contaminant and subarea. This is particularly true for the relative low density PCDD/F data ~~plotted~~presented in Figure 5.2~~1~~-8~~39, where a single extreme data point can skew the calculated ratio.~~

Box-Whisker Plots: Box-whisker plots were developed to visually compare the range and spread of chemical concentrations in the Study Area reach with the upstream reach, the downtown reach, and downstream reach of the lower Willamette River. The data plotted includes both detected and undetected values. Box-whisker plots are useful in displaying and comparing distributions between groups of data. These plots display differences between populations without making any assumptions of the underlying statistical distribution of the data sets. The spacing between the different parts of the box helps indicate the degree of dispersion (spread) and skewness in the data. The lower end of the box represents the 25th percentile (first quartile) and the upper end of the box represents the 75th percentile (third quartile) of each data population. The line in the center of the box represents the median of the data (i.e., half the data is below this value and half the data is above). The ends of the whiskers represent the minimum and maximum of each data population, which shows the spread of all the data in that population. The box-whisker plots included here were developed in Statistica.

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~~5.13.1~~5.2.1 Sediment Data Set

The sediment RI data set is composed of all Category 1 LWG and non-LWG data (refer to Table D1.3-1) collected within the down~~river~~ reach (RM 0 to 1.9), the RI Study Area reach (RM 1.9 to 11.8), the downtown reach (RM 11.8 to 15.3), and the upriver reach (RM 15.8 to 26), from May 1997 to July 2010. ~~The sediment RI data set is composed of~~

~~all Category 1 LWG and non-LWG data collected within the Study Area (below +13 ft NAVD88) from May 1997 to December 2007. Sediments collected below +13 ft NAVD88 include both subaqueous sediment and beach sediment. Sediment data are used to characterize contaminant distribution and potential source effects, to provide data necessary for the risk assessments, to provide data for the FS, and to refine the understanding of the physical dynamics of the river system.~~

The surface sediment data set includes all samples with intervals starting at 0 cm and extending to depths ranging to 40 cm bml.[13] The subsurface data set includes all samples collected at depths greater than 40 cm bml. The Upriver reach is dynamic and the channel is coarse-ggrained with finer-grained sediments generally restricted to small off-channel areas (Map 5.2-50), thus, most of the main channel above RM 20 could not be sampled with a grab sampler because the river bed is cobbled or hard. Further, there are limited subsurface samples due to the outcropping of basalt in the upper river reach.~~Summary statistics for grain size, TOC, and ICs in the surface and subsurface sediment samples from the Study Area are presented in Tables 5.1-1 and 5.1-2; the full data set is provided in Appendix D1.3. . These summary statistics do *not* include results from locations that were dredged or capped subsequent to sample collection. However, post-dredged sediment samples are included in the summary statistics.~~

Summary statistics for indicator contaminants, percent fines, and TOC in the surface and subsurface sediment samples for the entire RI Study Area reach are presented in Tables 5.2-1 and 5.2-2. The data from the RI Study Area were segregated into the eastern shore, navigation channel, and western shore and are presented by river mile in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. ~~The data segregated by eastern shore, navigation channel, and western shore are also presented by hydrodynamic reach in Tables 5.2-9 and 5.2-10, Tables 5.2-11 and 5.2-12, and Tables 5.2-13 and 5.2-14, respectively.~~ These summary statistics do *not* include results from locations that were dredged or capped subsequent to sample collection. However, post-dredged sediment samples are included in the summary statistics. Similar summary statistics are presented for the Upriver reach in Tables 5.2-15 and 5.2-16, the Downtown reach in Tables 5.2-17 and 5.2-18, and the Downstream~~river~~ reach in Tables 5.2-19 and 5.2-20.

~~Summary statistics for key physical parameters and allother COIs in the surface and subsurface sediment samples from the RI Study Area reach are presented in Tables D1.3-2 and D1.3-3. These summary statistics do *not* include results from locations that were dredged or capped subsequent to sample collection. However,~~

[13] The functional definition of surface sediments for this site is 0–30 cm based on physical system studies. However, the recorded lower depth of a set of sediment samples (i.e., shallow cores that begin at the mudline) in the nature and extent data set reached to 40 cm. These samples were grouped with the surface data set, thus extending the maximum depth for the surface horizon to 40 cm. Core samples that extended from the mudline to depths greater than 40 cm were grouped with the subsurface sediment data set.

Commented [A13]: Is there somewhere that provides the list of samples that were excluded from the statistics? If not, this must be provided in appendix D and referenced here.

Commented [A14]: Should be time frame. Was this from Round 2? Round 3? Provide more specific language describing what is meant by this statement.

Commented [A15]: This is now discussed in Section 5.1.

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~~post-dredged sediment samples are included in the summary statistics. Similar summary statistics are presented for the Upriver reach in Tables D1.3-4 and D1.3-5, the Downtown reach in Tables D1.3-6 and D1.3-7, and the Downstreamriver reach in Tables D1.3-8 and D1.3-9.~~

Commented [A18]: This is now discussed in Section 5.1.

~~5.13.2 Indicator Chemicals in Sediment~~

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~~The IC list for sediment is presented in Table 5.0-2. The selection of ICs was guided by the considerations detailed in Section 5.0. A total of 34 individual analytes and calculated chemical sums were identified as ICs for sediment. They are organized as follows:~~

- ~~PCBs~~
  - ~~Total PCBs*~~
  - ~~PCB TEQ (ND=0)~~
- ~~PCDD/Fs~~
  - ~~Total PCDD/Fs* and TCDD TEQ (ND=0)*~~
- ~~DDx~~
  - ~~Total DDx (sum of 2,4'- and 4,4'-DDD, DDE, DDT)*~~
  - ~~Total of 2,4'- and 4,4'-DDT~~
  - ~~Total of 2,4'- and 4,4'-DDE~~
  - ~~Total of 2,4'- and 4,4'-DDD~~
- ~~PAHs~~
  - ~~Total PAHs*~~
  - ~~Total cPAH BaPEq values~~
  - ~~Total LPAHs~~
  - ~~Total HPAHs~~
  - ~~Phenanthrene~~
  - ~~Naphthalene~~

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- ~~BAP~~
- ~~Petroleum Hydrocarbons~~
- ~~TPH~~
- ~~TPH - Diesel-range hydrocarbons (DRH)~~
- ~~TPH - Residual-range hydrocarbons (RRH)~~
- ~~SVOCs~~
- ~~BEHP*~~
- ~~Butylbenzyl phthalate~~
- ~~Pentachlorophenol~~
- ~~Hexachlorobenzene~~
- ~~Pesticides~~
- ~~Total chlordanes*~~
- ~~gamma-Hexachlorocyclohexane (HCH)~~
- ~~Aldrin*~~
- ~~Dieldrin*~~
- ~~Metals~~
- ~~Arsenic*~~
- ~~Cadmium~~
- ~~Chromium*~~
- ~~Copper*~~
- ~~Lead~~
- ~~Mercury~~
- ~~Nickel~~

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~~– Zinc*~~

~~• Organometallic Compounds~~

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~~– TBT*.~~

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~~This section focuses on the distribution of a subset of 13 ICs in surface and subsurface sediment within the Study Area, which are indicated with an asterisk (*) in the above list (total PCDD/Fs and TCDD TEQ are grouped as one chemical in this count). Although numerous contaminants that potentially pose risk to human health or the environment are comingled across the site, these 13 ICs were selected, in consultation with EPA, based on the preliminary risk evaluations and other site information, and match the contaminants presented and discussed in the site-wide CSM (Section 10). Of these, four contaminant groups—total PCBs, total PCDD/Fs (including TCDD TEQ), total DDx, and total PAHs—have been identified as bounding ICs based on the risk evaluations and their nature and extent are discussed in depth here. The discussion focuses primarily on the following items:~~

Commented [A20]: This was moved to intro to 5.2.

~~• A description of the data set for each contaminant, including sample counts, concentration range, and frequency of detection.~~

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~~• A discussion of the surface and subsurface concentration distributions in the Study Area organized by eastern nearshore, western nearshore, and navigation channel subareas.~~

~~• Additional information is provided for the four bounding ICs:~~

~~– The vertical trends in sediment concentrations~~

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~~– The relationship of subsurface sediment to surface sediment~~

~~– The nature and composition of these complex chemical groups and distribution patterns.~~

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~~The discussion of the other 9 ICs in the subset is less comprehensive, omitting the data set description and referring instead to maps, tables, and figures to provide a complete picture of the distribution of these contaminants. The data for the remaining 21 sediment ICs is presented in Appendix D1. In Section 10, contaminant distributions across abiotic and biotic media and in relation to specific potential sources are presented in more detail for the subset of 13 ICs.~~

~~5.13.3 Description of Sediment Presentation Tools~~

Commented [A21]: This was incorporated into Section 5.2.

~~The sediment RI data set is composed of all Category 1 LWG and non-LWG data collected within the Study Area (below +13 ft NAVD88) from May 1997 to December 2007~~July 2010~~. The sediment chemistry distributions are depicted in five graphical~~

~~formats: surface plan-view concentration maps and subsurface core concentration maps (Maps 5.21-1 through 5.21-28), scatter-plot graphs (Figures 5.21-1 through 5.21-32), and histograms and stacked bar charts (Figures 5.1-33 through 5.1-457). At EPA's request, cCore plots showing a higher level of detail have been produced for the following ICsindicator contaminants:~~

- ~~Total PCBs~~
- ~~Total DDx~~
- ~~TCDD TEQ~~
- ~~Total PAHs~~
- ~~Total cPAH BaPEq values.~~

~~These more detailed core plot maps were developed for these particular contaminants because they are more prevalent throughout the Study Areaare presented in Appendix D1.2.~~

~~Maps and scatter-plot graphs of surface and subsurface concentrations for the remaining 21 ICs, plus percent fines and TOC, are included in Appendices D1.1 and D1.4, respectively. Appendix D1.3 provides statistical summaries of all sediment analytes.~~

Commented [A22]: This paragraph was incorporated into Section 5.0.

~~**Surface Chemistry Maps:** The plan-view concentration maps present all surface sample data using color-coded dots that correspond to a concentration scale for that particular chemical. The concentration ranges (or intervals) used in color-coding the chemical data shown on the maps were based on the frequency distributions (i.e., natural breaks) in the data set for these and has no environmental significance. Non-detected concentrations are differentiated from detected concentrations on the surface maps by a dot in the center of the sample symbol (i.e. ⊙). The maps include data points from locations that were dredged or capped subsequent to the collection of the sample(s) (shown by a circle centered around the sample symbol [i.e., ◎]).[14,15] Data from these areas are presented to show spatial patterns of chemicals from a historical perspective. In addition, the surface maps include histograms showing the distributions and frequencies of the detected and non-detected results. Data from all samples shown on the maps are included in the histograms.~~

~~The concentration ranges (or intervals) used in color-coding the chemical data shown on the maps (e.g., the threshold value for the red labels) were based on the frequency~~

Commented [A23]: This information was incorporated into 1st paragraph.

~~[14] For example, all data shown for locations *within the capped area* at the M&B site (see Maps 2.2-1i and 2.2-2i) are from surveys completed between 1999 and 2002, prior to capping. These data are shown on the surface and subsurface core plan-view maps and included in the map histograms; however, they are not included in the other sediment data presentations (i.e., scatter plots, histograms, and stacked bar charts, discussed below).~~

~~[15] Surface interval sample locations G088, G087, and G091 collected in 2004 in the International Terminals Slip were dredged subsequent to sampling. These locations were resampled in 2005 at C088, C087, and C091.~~

~~distributions (i.e., natural breaks) in the historical data set for these compounds and as approved or modified by EPA for use in the Programmatic Work Plan. These concentration range intervals were also used in the Round 2 Report.~~

~~**Subsurface Core Maps:** The core maps show the distribution of ICs contaminants with depth at each of the subsurface sediment sampling stations (these maps also include the surface sample data). Inset maps for densely sampled core areas are provided in most cases, unless the core samples in these areas were archived (i.e., for possible future chemical analysis). In these maps, the actual core station is marked with a triangle (i.e., △). The core segment divisions displayed on the maps are scaled to the thickness of each sample interval. Note that these maps do include cores from locations that were subsequently dredged or capped, as indicated on the maps. Cores taken post-dredging are also included on the maps. The subsurface concentration maps do not indicate samples where concentrations are based on partial sums (i.e., A-qualified data; the few cases where data are based on partial sums are from non-LWG studies).~~

~~**Scatter Plots:** Scatter plots of the distribution of analytes detected contaminants in surface and subsurface sediment per river mile are presented in Figures 5.1-1 through 5.1-32, and in Appendix D1.4. To aid in differentiating potential concentration trends, the data in these plots are further separated into eastern nearshore, western nearshore, navigation channel, and Multnomah Channel stations as defined by the federal navigation channel boundary. The areas falling into these categories are shown in Map 5.1-29. Unlike the plan-view maps, the scatter plots do *not* include data for samples from locations that have been subsequently dredged or capped.~~

~~**Histograms:** Histograms were developed to supplement the subsurface core maps and support examination of vertical trends in chemical concentrations with depth in the sediment column. The histograms compare the absolute magnitude of the ratios ofaverage surface and subsurface sediment chemical concentrations for the bounding ICsindicator contaminants on subarea basis (e.g., RM 8-9 west of channel; see Figures 5.1-33, 5.1-39, 5.1-42, and 5.1-45). The ratios were calculated by dividing the mean of all detected surface sample concentrations in a given subarea by the mean of all detected subsurface core interval samples in that subarea. The absolute magnitude of the ratios is plotted on the histograms (i.e., where the subsurface mean is greater than the surface mean, the inverse of the ratio is plotted). The actual surface and subsurface concentrations for individual samples by river mile are shown on the scatter plots (Figures 5.1-1 through 5.1-32 noted above), and as with the scatter plots, the histograms do *not* include data from dredged or capped samples.~~

~~The y-axis in the plots is centered on a value of 0, which represents no numerical difference between the mean surface and subsurface concentrations for a given subareathe vertical horizon (40 cm bml) between the surface and subsurface samples. Values Bars extending downward from the y-axis indicate areas wheredeptict the mean of subsurface mean values exceeds the surface mean. Bars extending upward show where the surface sediment means are greater. The y-axis value indicates the absolute~~

magnitude of the differences between the surface and subsurface means. In some instances, a ratio could not be determined because only surface sediments were analyzed for the bounding ICs in that subarea. Subareas included east, navigation channel, and west zones for each river mile in the Study Area, as well as Multnomah Channel, Swan Island Lagoon, downstream reach (RM 0–2), Multnomah Channel, and Swan Island Lagoonupriver reach (RM 15.3-26), and downtown reach (RM 11.8-15.3). Mean concentrations were also calculated for each zone in the entire Study Area as a whole (see leftmost column in each figure).

These histograms are useful in providing a visual summary of spatially averaged surface/subsurface trends throughout the Study Area and, therefore, for identifying ongoing versus historical sources of contamination. However, some caution is needed in interpreting the trends due to the biased nature of the RI sampling program (i.e., subsurface core samples were generally focused on known areas of contamination, whereas surface samples were distributed more widely). Consequently, these histograms should be examined in conjunction with the subsurface core maps in evaluating surface to subsurface trends for a specific IC contaminant and subarea. This is particularly true for the relative low density PCDD/F data plotted in Figure 5.1-39, where a single extreme data point can skew the calculated ratio.

Stacked Bar Charts: Stacked bar charts are designed to reveal potential distinctive patterns in the relative abundance of bounding IC components (e.g., homologs, isomers). The analyte components are shown in the stacked bars as a percent of the total concentration, while the total concentration of the IC is displayed as a line on a logarithmic scale. Station location labels are provided on the x-axis, and river mile is indicted on the secondary x-axis along the top of the chart. Subsurface figures display only the sample interval with the maximum concentration of the analyte, per core station location. The stacked bar charts do *not* include data from dredged or capped samples.

Commented [A24]: These can be moved to Appendix D with discussion of patterns and trends.

Any patterns apparent in the stacked bar charts must be interpreted with caution. Changes in chemical composition and apparent trends shown by the bar charts may be indicative of significant patterns (e.g., distinctive source contributions), or they may be within the range of normal data variability. Further, it should be kept in mind that the display of constituent components as a percentage of the total may, in some cases, amplify the visual impact of what are in fact small-scale changes in sample composition. It is important to emphasize that source identification and allocation are complex multivariate problems. The pattern shifts discussed in the following sections based on stacked bar chart presentations may be suggestive, but cannot be interpreted directly as or attributed to localized sources. Such a characterization would require rigorous quantitative forensic analysis, which is outside the scope of this RI/FS.

~~5.13.5 Sampling Methods~~

Commented [A25]: This is discussed in Section 2. Does not add to discussion in this section.

~~LWG surface sediment samples were collected in a consistent, repeatable manner with a stainless-steel, 0.3-m^2 hydraulic power-grab sampler. The maximum penetration of the power-grab sampler was approximately 30 cm. Non-LWG surface samples were collected using a variety of sampling devices, including ponar samplers, power grabs, Eckman samplers, box cores, and spoons. A limited number of non-LWG surface samples were collected from the mudline to depths of 30 to 40 cm bml, and these data are also included in the RI surface sediment data set.~~

~~Subsurface sediment was collected by the LWG using a customized vibracorer equipped with either 14-ft or 20-ft core tube. Non-LWG subsurface samples were collected by a variety of methods and depths, the most common being a vibracore, followed by a "driven tube." The driven tube could include the vibracore, impact, or gravity methods. Other coring samplers included gravity corer, macro-core sampler, impact corer, hand core, split-spoon sampler, Mudmole™, and steam auger.~~

~~5.13.8~~5.2.2 Total PCBs in Surface and Subsurface Sediment ~~(Congeners and Aroclors)~~

Several data presentations for the surface and subsurface total PCB data set within the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. ~~This subsection presents the correlation between total PCBs calculated as congeners and as Aroclors, summarizes the surface and subsurface distribution of total PCB concentrations in the Study Area, compares discusses the relationship between the total PCB congener and Aroclor concentrations in surface and subsurface samples, and discusses PCB homolog and Aroclor patterns across the Study Area. For the purpose of sediment characterization, total PCB congener concentrations represent the sum of detected congener concentrations in a sample. In cases where no congeners were detected, the single highest detection limit of all congeners analyzed is used to represent the total value. Similarly, total PCB Aroclor values reflect the sum of detected Aroclors in a sample.~~

~~To simplify characterization of PCBs in the Study Area, the total PCB congener and total Aroclor data were combined into a single data set of total PCBs. These total PCB data values calculated from both congeners and Aroclors were used to create Maps 5.21-1 and 5.21-2a-om. The total PCB data set consists of the result for total PCB congeners for each sample when available (with one exception), and the result for total Aroclors when no total PCB congener data are available. Priority was given to PCB congener data based on the greater specificity and accuracy of the laboratory method for congeners (see Appendix D1.5). The exception is that total Aroclor data were selected to represent total PCBs for Round 2A beach sediment samples because the beach samples were only analyzed for coplanar PCB congeners, which constitute a small fraction of the total PCBs. Congener analyses for the remaining LWG sediment samples included all 209 congeners. Total PCB concentration data for the Study Area~~

~~are available for 1,184 surface and 1,325 subsurface samples. Most of the PCB data are based on Aroclor analyses (Tables 5.1-1 and 5.1-2). Maps 5.1-30 and 5.1-31 display the locations of surface and subsurface sediment samples analyzed for PCBs and indicate whether PCB congener data, Aroclor data, or both are available.~~

The distribution of ~~maximum~~ total PCB concentrations at each surface sediment sampling station~~s~~ throughout the Study Area is depicted on Map 5.2~~1~~-1; concentrations with depth at subsurface stations are depicted on Maps 5.2~~1~~-2a–~~om~~. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented. Detailed subsurface sediment chemistry in the Study Area is presented on Maps 5.2-3a-ff,~~.~~ ~~Figure 5.2-1 provides~~ including a ke~~ye~~y for interpreting the detailed subsurface chemistry maps.

~~-~~Figures 5.2-1~~2~~ and 5.2-2~~3~~ present scatter plots of ~~The~~the total PCB ~~complete~~ data set for surface and subsurface sediment in the Study Area ~~is plotted on scatter plots presented in Figures 5.1-1 and 5.1-2~~, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

~~Scatter plots for total PCB congeners and Aroclors are shown in Figures 5.1-3 through 5.1-6.~~ The summary statistics ~~values shown in Tables 5.1-1 and 5.1-2~~ for total ~~Aroclors and total~~ PCB~~ congener~~s in ~~in~~ surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2 ~~indicate overall higher sample concentrations of total PCB when summing congeners~~. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total PCB data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only~~of~~ detected values and for combined detect and nondetect values~~, respectively~~. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-3~~4~~.

Data sets for the Upriver reach, Downtown reach, and Downstream~~river~~ ~~R~~reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-36. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream~~river~~ reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream~~river~~ reach is presented in Figure 5.2-4~~5~~. ~~The higher concentrations measured by summing congeners are not a result of differences in laboratory methodology, but rather are attributable to a more targeted sample selection process, i.e., samples selected for PCB congener analysis frequently targeted areas known or suspected to have relatively high PCB contamination.~~

~~5.13.8.1 Total PCB Congener and Aroclor Correlation~~

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~~The relationship between total PCB congener and total Aroclor concentrations is discussed in detail in Appendix D1.5. Both methods represent the total PCB concentrations well, and summed total PCB concentrations are fairly comparable between methods in most cases. The surface sediment correlation (coefficient of determination) between same-sample congener and Aroclor totals was~~ $r^2 = 0.761$~~, and the subsurface correlation was~~ $r^2 = 0.476$~~. Plots of these regressions are presented in Appendix D1.5. For all data (sediment, sediment trap, and biota),~~ r^2 ~~was 0.70. PCB totals based on congeners and Aroclors did not correspond well for 11 sediment samples (i.e., an order of magnitude difference between the total congener and total Aroclor results); these are also described in Appendix D1.5. The evaluation of the relationship between PCB congener and PCB Aroclor concentrations in Appendix D1.5 indicates that total Aroclor data may overpredict total PCB congeners in concentrations below ~750 µg/kg total Aroclors and may result in underprediction above 750 µg/kg.~~

~~PCB congener data better represent total PCB concentrations than Aroclor data, as the congener method is less affected by "weathering," non-PCB interferences, and subjective Aroclor identifications. For this reason, in this report, total PCB congener concentrations are given priority over total Aroclor concentrations when total PCB congener data exist for any given sample. Because measured total PCB concentrations are fairly comparable between methods in most cases (especially when measurement error is considered), it is useful to use Aroclor concentrations when no PCB congener data exist. Combining the PCB data in this way provides greater spatial and temporal coverage than using congener data alone.~~

5.2.2.1 Total PCB Data Set ~~for Sediments~~

~~Total PCB values calculated from both congeners and Aroclors were used to create the total PCB data set for sediments. The total PCB data set consists of the result for total PCB congeners for each sample when available (with one exception), and the result for total Aroclors when no total PCB congener data are available. Priority was given to PCB congener data based on the greater specificity and accuracy of the laboratory method for congeners (see Appendix D1.5). The exception is that total Aroclor data were selected to represent total PCBs for Round 2A beach sediment samples because the beach samples were only analyzed for coplanar PCB congeners, which constitute a small fraction of the total PCBs. Congener analyses for the remaining LWG sediment samples included all 209 congeners. Total PCB concentration data for the Study Area are available for 1,184 surface and 1,325 subsurface samples. Most of the PCB data are based on Aroclor analyses (Tables 5.1-1 and 5.1-2). Maps 5.1-30 and 5.1-31 display~~

~~the locations of surface and subsurface sediment samples analyzed for PCBs and indicate whether PCB congener data, Aroclor data, or both are available.~~

The surface and subsurface data set includes PCBs analyzed for both Aroclors and congeners. For the purpose of sediment characterization, total PCB congener concentrations represent the sum of detected congener concentrations in a sample. In cases where no congeners were detected, the single highest detection limit of all congeners analyzed is used to represent the total value. Similarly, total PCB Aroclor values reflect the sum of detected Aroclors in a sample.

The relationship between total PCB congener and total Aroclor concentrations is discussed in detail in Appendix D1.5. ~~Both methods represent the total PCB concentrations well, and summed total PCB concentrations are fairly comparable between methods in most cases.~~ The surface sediment correlation (coefficient of determination) between same-sample congener and Aroclor totals was $r^2 = 0.761$, and the subsurface correlation was $r^2 = 0.476$. Plots of these regressions are presented in Appendix D1.5. For all data (sediment, sediment trap, and biota), r^2 was 0.70. PCB totals based on congeners and Aroclors did not correspond well for 11 sediment samples (i.e., an order of magnitude difference between the total congener and total Aroclor results); these are also described in Appendix D1.5. The evaluation ~~of the relationship between PCB congener and PCB Aroclor concentrations in Appendix D1.5~~ indicates that total Aroclor data may overpredict total PCB congeners in concentrations below ~750 µg/kg total Aroclors and may result in underprediction above 750 µg/kg.

~~It was concluded that~~For this reason, PCB congener data was determined to better represent total PCB concentrations than Aroclor data, as the congener method is less affected by “weathering,” non-PCB interferences, and subjective Aroclor identifications.

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~~For this reason, i~~In this report, total PCB congener concentrations are given priority over total Aroclor concentrations when total PCB congener data exist for any given sample based on the greater specificity and accuracy of the laboratory method for congeners. Because measured total PCB concentrations are fairly comparable between methods in most cases (especially when measurement error is considered), it is useful to use Aroclor concentrations when no PCB congener data exist, which is the majority of the samples. Combining the PCB data in this way provides greater spatial and temporal coverage than using congener data alone due to the lack of congener data available.

The summary statistics values shown in Tables 5.2-1 and 5.2-2 for total Aroclors and total PCB congeners indicate overall higher sample concentrations of total PCB when summing congeners. The higher concentrations measured by summing congeners are not a result of differences in laboratory methodology, but rather are attributable to a more targeted sample selection process, i.e., samples selected for PCB congener analysis frequently targeted areas known or suspected to have relatively high PCB contamination.

Consequently, the total PCB data set consists of the result for total PCB congeners for each sample when available (with one exception[16]), and the result for total Aroclors when no total PCB congener data are available for a particular sampling location. ~~Priority was given to PCB congener data based on the greater specificity and accuracy of the laboratory method for congeners (see Appendix D1.5).~~ Congener analyses for the remaining LWG sediment samples included all 209 congeners. Total PCB concentration data for sediment within the Study Area are available for 1,318~~870~~ surface and 1,543~~702~~ subsurface samples. Most of the total PCB data are based on Aroclor analyses (Tables 5.2-1 and 5.2-2). Maps 5.2-4 and 5.2-5 display the locations of surface and subsurface sediment samples analyzed for PCBs and indicate whether PCB congener data, Aroclor data, or both are available.

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~~5.13.8.2~~ Total PCBs in Surface Sediment

5.2.2.2

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Upriver Reach (RM 15.3 to 28.4)

Total PCBs were analyzed in 81 surface sediment samples and detected in 42 samples within the Upriver reach (detection frequency of 52 percent), with detected concentrations ranging from 0.29 J ug/kg to 31 ug/kg (Table 5.2-11). Tables 5.2--13 and 5.2-14 show that there are 4 data points greater than 10 ug/kg. The majority of the detected data set (80 percent) is comprised of concentrations ranging between 1 and 10 ug/kg. Another 4 samples, or 10 percent of the detected data set, was detected at a concentration less than 1 ug/kg. The mean total PCB concentration in this reach is 4.48 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

Total PCBs were analyzed in 265 surface sediment samples and detected in 195 samples within the Downtown reach (detection frequency of 74 percent), with detected concentrations ranging from 0.798 J ug/kg to 19,700 ug/kg (Table 5.2-15a) and a mean concentration of 612 ug/kg. Total PCB concentrations in surface sediment varied along the ~~Study Area~~Downtown reach (Map 5.2-36). The map shows that the majority of the samples with concentrations exceeding 1,000 ug/kg are located along the western shoreline between RM 13.5 and 14.1, which is the location of the Zidell facility.

Tables 5.2-17~~3~~ and 5.2-18~~4~~ show that there are 3~~4~~ data points greater than 10,000 ug/kg. There are 12 detected values between 1,000 and 10,000 ug/kg. Surface sediment values greater than 1,000 ug/kg accounts for eight percent of the detected data set. An addional 51 samples, 26 percent of the detected data set, were detected at concentrations between 100 and 1,000 ug/kg. ~~The majority~~Almost half of the detected data set (42~~80~~

[16] The exception is that total Aroclor data were selected to represent total PCBs for Round 2A beach sediment samples because the beach samples were only analyzed for coplanar PCB congeners, which constitute a small fraction of the total PCBs.

percent) is comprised of concentrations ranging between 10 and 100 ug/kg. Another 47 samples, or 24 percent of the detected data set, is between 1 and 10 ug/kg and only one sample was detected at a concentration less than 1 ug/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. ~~In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Zidell data.~~ Total PCBs were analyzed in 111 surface sediment samples (detection frequency of 73 percent), with concentrations ranging from 1.27 ug/kg to 19,700 ug/kg. The mean total PCB concentration for this area is 1,320 ug/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15c), the range of total PCB concentrations in surface sediment is from 0.798 J ug/kg to 4,200 ug/kg with a mean concentration of 108 ug/kg.~~Another 4 samples, or 10 percent of the detected data set, was detected at a concentration less than 1 ug/kg.~~

~~Surface sediment chemistry in Map 5.2-36~~

~~Stats Table 5.2-15~~

~~Order of Mag Table 5.2-17 and 18~~

Study Area Reach (RM 1.9 to 11.8)

Total PCBs were detected in 1,052~~940~~ surface sediment samples within the Study Area (detection frequency of 80~~79~~ percent), with detected concentrations ranging from 0.851 J~~T~~ µg/kg to 35,400 µg/kg (Table 5.2~~1~~-1). ~~Ninety-five percent of the concentrations in surface samples were less than 641 V µg/kg.~~

Total PCB concentrations in surface sediment varied along the Study Area (Figure 5.2-1~~2~~). ~~With few exceptions, concentrations were generally less than 100 µg/kg throughout the navigation channel, whereas many areas in the nearshore zones contained concentrations greater than 100 µg/kg in surface samples (Figure 5.1-1).~~ Total PCB concentrations exceeding 1,000 µg/kg (1 ppm) in the scatter plots are indicated in red on Map 5.2~~1~~-1.

Several~~A~~ prominent peaks (>1,000 ug/kg) in the surface data are identified in ~~from~~ the eastern nearshore zone (see Figure 5.2-1~~2~~) from RM 1.9 to RM 4, RM 6 to 7, Swan Island Lagoon, and RM 11-11.8. Map 5.2-1 shows that these peaks are clustered in areas within these river mile ranges rather than dispersed throughout the area. Mean concentrations (see Table 5.2-3) for these areas in the eastern nearshore zone are: 663 ug/kg for RM 1.9 to 3; 369 ug/kg for RM 3 to 4; 223 ug/kg for RM 6 to 7; 373 ug/kg for Swan Island Lagoon; and 495 ug/kg for RM 11 to 11.8.

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There ~~are~~is also a promine~~ent~~ant peak identified in the western nearshore zone ~~occurred~~ from RM 8 to RM 10; ~~at RM 8.8, where~~ the highest surface concentration (35,400 ug/kg) in the data set was detected at RM 8.8 (Station G453).~~–~~ Map 5.2-1 also shows that this peak is clustered in an area within this river mile range rather than dispersed throughout the area. Mean concentrations (see Table 5.2-7) for this area in the western nearshore zone are: 978 ug/kg for RM 8 to 9; and 341 ug/kg for RM 9 to 10.

The only promi~~e~~ne~~a~~ant peak in the n~~N~~avigation c~~C~~hannel zone is at RM 11 to 11.8, which is linked with the eastern nearshore data rather than an area within the entire navigation channel (Map 5.2-1). The maximum concentration was 5,900 ug/kg and the mean concentration was 292 ug/kg (Table 5.2-5).

Tables 5.2-9 and 5.2-10 show that there are only 2 data points greater than 10,000 ug/kg. These are located in the western nearshore zone at RM 8.8 and in Swan Island Lagoon. There are 37 detected values between 1,000 and 10,000 ug/kg, which are within the ~~promenant~~prominent peak areas described above. ~~All s~~Surface sediment values greater than 1,000 ug/kg accounts for four~~3.7~~ percent~~%~~ of the detected data set (Map 5.2-1). An addional 203 samples, 19 percent~~%~~ of the detected data set, were detected at concentrations between 100 and 1,000 ug/kg. These samples are depicted as green, yellow and orange on Map 5.2-1. Over half of the detected data set (621 samples; 59 percent~~%~~) is comprised of concentrations ranging between 10 and 100 ug/kg. Another 188 samples, or 18 percent~~%~~ of the detected data set, is between 1 and 10 ug/kg and only one~~1~~ sample was detected at a concentration less than 1 ug/kg.

Down~~nriver~~stream Reach (RM 0 to 1.9)

Total PCBs were analyzed in 25 surface sediment samples and detected in 16 samples within the Downstream~~river~~ reach (detection frequency of 64 percent), with detected concentrations ranging from 1.03 J ug/kg to 410 ug/kg (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there is one data point greater than 1,000 ug/kg. An additional 8 samples, 38 percent of the detected data set, were detected at concentrations between 100 and 1,000 ug/kg. Over half of the detected data set (11 samples; 52 percent) is comprised of concentrations ranging between 10 and 100 ug/kg. One sample was detected at concentrations between 1 and 10 ug/kg ~~while~~and no samples were detected at a concentration less than 1 ug/kg. The mean total PCB concentration in this reach is 34 ug/kg.~~Stats Table 5.2-19~~

~~Order of Mag Table 5.2-21 and 22~~

~~The highest subsurface concentration was also found in this vicinity (Station C455; 30–153 cm bml).~~

~~5.13.8.3~~5.2.2.3 Total PCBs in Subsurface Sediment

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Upriver Reach (RM 15.3 to 28.4~~6~~)

Total PCBs were analyzed in three~~3~~ subsurface sediment samples between RM 15.4 and 16 and were not detected any samples within the Upriver reach. The maximum detect level was 11 U ug/kg (Table 5.2-12). ~~Stats Table 5.2-12~~

~~Order of Mag Table 5.2-13 and 14~~

Downtown Reach (RM 11.8 to 15.3)

Total PCBs were analyzed in 110 subsurface sediment samples and detected in 59 samples within the Downtown reach (detection frequency of 54 percent), with detected concentrations ranging from 1.4 J ug/kg to 610 ug/kg (Table 5.2-16a) and a mean concentration of 92 ug/kg. Tables 5.2-17 and 5.2-18 show that there are 15 detected values between 100 and 1,000 ug/kg. Almost half of the detected data set (31 samples; 44 percent of the detected data set) were detected at concentrations between 10 and 100 ug/kg. Another 13 samples, or 22 percent of the detected data set, is between 1 and 10 ug/kg no samples were detected at a concentration less than 1 ug/kg. Only two subsurface samples were in analyzed in the vicinity of the Zidell facility; the concentrations were 140 ug/kg and 190 ug/kg.

~~Stats Table 5.2-16~~

~~Order of Mag Table 5.2-17 and 18~~

Study Area Reach (RM 1.9 to 11.8)

~~Study Area Reach~~

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Total PCBs were detected in 939~~862~~ subsurface samples within the Study Area (detection frequency of 61~~5~~ percent), with detected concentrations~~ and~~ ranging~~ed~~ from 0.00138 J µg/kg to 36,800 µg/kg (Table 5.2~~1~~-2).

Similar to surface sediment, total PCB concentrations in the subsurface also varied within the Study Area (Figure 5.2~~1~~-23~~2~~; Maps 5.2~~1~~-2a–o and 5.2-3a-ff~~m~~).

Several prominent peaks (>1,000 ug/kg) in the subsurface data are identified in the eastern nearshore zone (see Figure 5.2-2~~3~~) from RM 1.9 to RM 4, RM 5 to RM 6, Swan Island Lagoon, and RM 11 to 11.8. ~~These areas all align with the locations where surface sediment concentrations are greater than 1,000 ug/kg (Maps 5.2-2a-o and 5.2-3a-ff), except surface sediment concentrations were elevated from RM 6 to RM 7 where subsurface is elevated from RM 5 to RM 6.~~ Mean concentrations (see Table 5.2-4) for these areas in the eastern nearshore zone are: 521 ug/kg for RM 1.9 to RM 3; 1,530 ug/kg for RM 3 to RM 4; 369 ug/kg for RM 5 to RM 6; 560 ug/kg for Swan Island Lagoon; and 464 ug/kg for RM 11 to RM 11.8.

There is also a prominent peak identified in the western nearshore zone from RM 7~~8~~ to RM 10~~ that corresponds with the location of elevated surface sediment concentrations.~~ The highest subsurface concentration (36,800 ug/kg) ~~was~~is also detected in this area (Station C455; 30–153 cm bml). Mean concentrations (see Table 5.2-8) for this area in the western nearshore zone are: 177 ug/kg for RM 7 to RM 8; 931 ug/kg for RM 8 to RM 9; and 424 ug/kg for RM 9 to RM 10.

The only prominent peak in the Navigation Channel zone is from RM 10 to RM 11.8. This area is greater than, but encompasses, the area of elevated concentrations in surface sediment. Mean concentrations (see Table 5.2-6) for this area in the navigation channel are: 443 ug/kg for RM 10 to RM 11; and 107 ug/kg for RM 11 to RM 11.8. Maps 5.2-2l and m show that the RM 10 to 11 subsurface data for the Navigation Channel zone are associated with the western nearshore area whereas the RM 11 to RM 11.8 subsurface data area associated with the eastern nearshore area.

Tables 5.2-9 and 5.2-10 show that there are 6 data points greater than 10,000 ug/kg. These are located in the eastern nearshore zone from RM 3 to RM 4, Swan Island lagoon, and the western nearshore zone from RM 8 to RM 9. There are an additional 40 detected values between 1,000 and 10,000 ug/kg, which are within the prominent peak areas described above. Subsurface sediment values greater than 1,000 ug/kg accounts for five percent of the detected data set. An additional 319 samples, 34 percent of the detected data set, were detected at concentrations between 100 and 1,000 ug/kg. Half of the detected data set is comprised of concentrations ranging between 10 and 100 ug/kg. Another 88 samples (nine percent) is between 1 and 10 ug/kg and 20 samples (two percent) ~~were~~are detected at less than 1 ug/kg.

Downstream~~river~~ Reach (RM 0 to 1.9)

Total PCBs were analyzed in 26 subsurface sediment samples and detected in 13 samples within the Downstream~~river~~ reach (detection frequency of 50 percent), with detected concentrations ranging from 5 ug/kg to 250 ug/kg (Table 5.2-20). Tables 5.2-21 and 5.2-22 show that there are three data points greater between 100 and 1,000 ug/kg. An additional 8 samples, 62 percent of the detected data set, ~~were~~are detected at concentrations between 10 and 100 ug/kg. Two samples were detected at concentrations between 1 and 10 ug/kg and no samples were detected at a concentration less than 1 ug/kg. The mean total PCB concentration in this reach is 67 ug/kg.~~Stats Table 5.2-20~~

~~Order of Mag Table 5.2-21 and 22~~

~~With few exceptions, concentrations were generally less than 100 µg/kg throughout the navigation channel. Areas with subsurface concentrations greater than 1,000 µg/kg~~

~~generally occurred in areas with surface concentrations also greater than 1,000 µg/kg (Figures 5.1-1 and 5.1-2).~~

~~The highest subsurface concentration was also found in this vicinity (Station C455; 30–153 cm bml).~~

~~5.13.8.5~~5.2.2.4 Total PCB Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships ~~were~~ are examined by ~~calculating ratios of mean total PCB concentrations (i.e., surface/subsurface) for the Study Area; for the east, middle, and west sides of the Study Area; for Multnomah Channel; and for Swan Island Lagoon. Ratios compared all surface and all subsurface sample intervals and excluded non-detected data. The magnitude of surface and subsurface mean total PCB concentrations were then plotted in a histogram to illustrate general trends in surface and subsurface chemical distributions. Statistical summaries for river mile reaches are provided in Table 5.1-3.~~ comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach.

There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean surface sediment concentration in this reach is 4.48 ug/kg. All the subsurface samples ~~were~~are not ~~n-~~detected with a maximum detection level of 11 ug/kg.

The surface sediment conentrations in the downtown reach were greater than subsurface concentrations. The mean surface concentration ~~was~~is 612 ug/kg, while the mean subsurface concentration ~~was~~is 92 ug/kg.

Total PCB concentrations ~~were~~ are generally ~~higher~~ greater in subsurface sediments than in surface sediments within the Study Area as a whole. The mean suface sediment concentration in the Study Area ~~was~~is 220 ug/kg and the mean subsurface sediment concentration ~~was~~is 351 ug/kg (Tables 5.2-1 and 5.2-2)~~(left side of Figure 5.1-33),~~[17] ~~with localized exceptions~~. Figure 5.2-3~~4~~ shows that mean concentrations are greater in the nearshore areas than in the navigation channel and the eastern nearshore zone is greater than the western nearshore zone. It also shows that concentrations are generally greater in the subsurface sediment than in surface sediment.

In the eastern nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles zones except from RM 1.9 to 3, RM 6 to 7, RM 10 to

~~[17] Note that the magnitude of mean surface/mean subsurface concentration ratios above "0" in Figure 5.1-33 indicate higher mean surface sediment concentrations while those below "0" reflect higher mean subsurface sediment concentrations. In situations where only surface samples were analyzed (i.e., RM 2–3 west bank, and RM 10–11 west bank), a ratio could not be calculated and is indicated by an asterisk on the figure.~~

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11, and RM 11 to 11.8. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles except RM 8 to 9. The subsurface sediment concentrations in the navigation channel are generally greater than the surface sediment concentrations except from RM 11 to 11.8.

~~Where mean surface sediment total PCB concentrations are greater than mean subsurface concentrations the magnitude of difference is generally low (less than twice the mean subsurface concentration), with the exception of the navigation channel at RM 11 to 11.8. Higher surface sediment concentrations on the east side the navigation channel between RM 11 and 11.8 are also evident in the core plots (see Map 5.1-2m), indicating a probable ongoing source.~~

~~5.13.8.6 Patterns and Trends of PCBs in Sediment~~

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~~This subsection includes a general description of the distribution of PCB homologs and Aroclors in sediment to provide information that may be used to infer the presence of different sources and PCB transport within the Study Area. Aroclor distributions are compared to homolog distributions to evaluate the Aroclor identifications made by the laboratories.~~

~~PCB homologs are congener groups based on chlorination level (i.e., the number of chlorine atoms [1–10] bonded to the biphenyl molecule). All of the PCB congeners within each homolog group are isomers. Homolog groups are identified as monochlorobiphenyl (one chlorine atom [$C_{12}H_9C_l$]; monoCB) through decachlorobiphenyl (10 chlorine atoms [$C_{12}Cl_{10}$]; decaCB). Examples of the PCB congener content of Aroclors has been reported by several authors (e.g., Erickson 1997, Frame et al. 1996) and was used to present the PCB homolog content of Aroclors in Figure 5.1-34. Identification of PCB Aroclors at the analytical laboratory can be subjective if the PCB pattern in the sample does not closely reflect the Aroclor standards. This is frequently the case in environmental samples as a result of fate and transport processes, the presence of more than one Aroclor in a sample, and chromatographic interference. Differing sorption, solution, and volatilization rates for different congeners and degradation processes can lead to weathering of Aroclors in the natural environment. Varying degrees of weathering were observed in the sediment samples, with some samples exhibiting what appeared to be weathered Aroclor patterns and other samples exhibiting Aroclor patterns that closely resembled Aroclor standards. Complex mixtures of two or more Aroclors were also observed in many sediment samples. Additional discussion about weathering and comparison of PCB congener and Aroclor totals is provided in Appendix D1.5.~~

~~PCB homolog group sums were calculated by summing the constituent congener concentrations, following the summation rules for the RI data.[18] PCB homolog and~~

~~[18] Calculated totals for each homolog are the sum of all detected constituent congeners. Non-detected congeners in a homolog group are assigned a value of zero. If all congeners in a homolog group were not detected, then the homolog total is assigned the highest detection limit among the constituent congeners and qualified with a U.~~

~~Aroclor compositions for samples within the Study Area are presented as bar charts in Figures 5.1-35 through 5.1-38. The bar charts show the percent composition of individual PCB homologs and Aroclors for each sample. In this data presentation, non-detected (U-qualified) homologs and Aroclors were assigned a value of zero; therefore, they do not appear on the bar charts. The figures are organized to show the east zone, navigation channel, and west zone (relative to the top of the navigation channel boundary). The dominant homolog (i.e., the homolog group detected at the highest concentration) at each sampling location is displayed on Maps 5.1-32 and 5.1-33, and the dominant Aroclor at each sampling location (i.e., the Aroclor detected at the highest concentration) is shown on Maps 5.1-34 and 5.1-35. Subsurface homolog and Aroclor patterns are shown only for the depth interval with the highest PCB concentration at each location. The PCB composition at other depths may differ from that at the depth of maximum concentration.~~

~~Spatial variations in apparent PCB patterns are evident throughout the Study Area, and areas of high PCB concentrations often exhibit homolog patterns that appear distinct from surrounding areas of lower PCB concentrations. These variances in the relative abundances of the homolog groups potentially reflect the differences in the sources of the PCBs and the transport and weathering processes affecting the Aroclors. Overall, the tetrachlorobiphenyl (tetraCB), pentachlorobiphenyl (pentaCB), hexachlorobiphenyl (hexaCB), and heptachlorobiphenyl (heptaCB) homolog groups are predominant in the Study Area, with localized exceptions (Figures 5.1-35a–c and 5.1-36a–c). In the eastern nearshore zone, the overall chlorination level of PCBs in the surface and subsurface sediments tends to appear higher upriver in the Study Area and lower downstream. Between RM 6.7 and 11.3 in the eastern nearshore zone, the highest concentration samples are chiefly composed of hexaCBs and heptaCBs. The chlorination levels appear lower at several locations of higher PCB concentrations, from about RM 2 to 4 east, with a dominance of trichlorobiphenyls (triCBs), tetraCBs, and pentaCBs. Homolog patterns in areas of high PCB concentration appear to be more variable in the western nearshore zone.~~

~~The PCB homolog patterns in subsurface sediment appear generally similar to surface sediment patterns at the 37 locations where PCB congener data are available for both surface and subsurface sediment. However, PCB homolog patterns in subsurface sediment appear different from surface sediment at RM 2.8 (sample location LW3-G609/LW3-C609), RM 3.7 (sample location LW3-C093), and RM 8.4 (sample location LW3-C393) in the eastern nearshore zone; RM 10.1 (sample location LW3-G747) in the navigation channel; and at RM 5.1 (sample location LW3-G184), RM 7.7 (sample location LW3-G401), and RM 9.6 (sample location LW3-G738) in the western nearshore zone. As noted previously, patterns displayed by the stacked bar charts may or may not be statistically significant and indicative of different potential~~

~~For the bar chart presentations, U-qualified homologs and Aroclors are assigned a value of zero and, therefore, do not appear.~~

~~sources. Detailed forensic analyses would be required to distinguish significant patterns in the data and potential source contributions.~~

~~Aroclors 1248, 1254, and 1260 were identified throughout the Study Area (Figures 5.1-37a–h and 5.1-38a–d). Aroclor 1221 was identified locally in surface sediments, and Aroclors 1242 and 1268 were identified locally in both surface and subsurface sediments; however, these Aroclors were not widespread (Figures 5.1-37a–h and 5.1-38a–d). Within the Study Area, Aroclor 1016 was identified in one surface sediment sample, and Aroclors 1232 and 1262 were identified in one subsurface sediment sample each. Aroclor patterns in the subsurface sediments were also generally similar to the surface sediment patterns.~~

~~5.13.8.6.1 Comparison of PCB Homolog Patterns with Reported Aroclors~~

~~For areas with total PCB concentrations greater than 1,000 µg/kg and infrequently reported Aroclors, a comparison of identified Aroclors to the PCB homolog groups was made by comparing the Aroclor homolog profiles as presented in Figure 5.1-34. The PCB homolog data, where available, generally supported the Aroclor identifications of Aroclors 1242, 1248, 1254 and 1260, with two notable exceptions.~~

~~Near RM 8.8 (western nearshore zone) Aroclors 1242 and 1248 dominated the PCBs in surface and subsurface sediment, and concentrations greater than 1,000 µg/kg of Aroclor 1260 in surface sediment and Aroclor 1254 in subsurface sediment were also reported. Aroclors 1242 and 1248 are generally difficult to differentiate on a gas chromatogram and may be reported differently by different laboratories or analysts. The PCB homolog distribution in this area supports the identification of Aroclor 1242, although it does not definitively rule out the additional presence of Aroclor 1248 (Figures 5.1-37a–h and 5.1-38a–d). TriCBs were notably abundant in the sediment, often in a pattern that resembled Aroclor 1242 more than Aroclor 1248. The presence of dichlorobiphenyls (diCBs) further supports the identification of Aroclor 1242. Overall, the homolog patterns were very similar for the two samples in this area with the highest concentration (LW2-G453 and LW2-GBT028), even though the Aroclors identified in these samples were different. The reporting of two Aroclors in this area by the laboratories appears to reflect the difficulty of Aroclor identification rather than a difference in the PCBs present in the samples.~~

~~In samples with total PCB concentrations greater than 1,000 µg/kg at RM 2.1–2.5 (eastern nearshore zone), Aroclors 1248, 1254, and 1260 were identified in the surface and subsurface sediments in this area, and Aroclor 1242 was identified in five of the subsurface sediment samples. The PCB homolog distribution in this area was consistent with the identification of Aroclor 1248 as the predominant Aroclor in the surface sediments. However, for some subsurface samples (e.g. LW2-C015-B) the homolog pattern was not consistent with the reported Aroclors. Aroclors 1254 and 1260 were reported as dominant in these samples, but the homolog profiles for these samples resemble the profile for Aroclor 1242 or 1248, with a potential contribution of~~

~~Aroclors 1254 or 1260. The lack of agreement between the homolog profiles and Aroclor identifications suggests the influence of weathering effects.~~

~~Aroclors not commonly reported in the Study Area (i.e., identified in fewer than 100 sediment samples or Aroclors other than 1242, 1248, 1254, and 1260) were also evaluated using PCB homolog data as described in the following paragraphs.~~

~~Aroclor 1221 was reported in surface sediment in the eastern nearshore zone and eastern edge of the navigation channel between RM 9.3 and 10 at concentrations up to 109 µg/kg (Station G472). However, the PCB homolog pattern is not consistent with Aroclor 1221 in the two samples from this area that were analyzed for PCB congeners. MonoCBs and diCBs are the dominant homologs in Aroclor 1221 (Erickson 1997; Figure 5.1-34), but tetra- through heptaCBs dominated the homolog profiles in this area. The same homolog profile was also present at adjacent location BT031, which was sampled at a later date and analyzed by a different lab, and for which Aroclor 1221 was not identified. Based on the PCB homolog patterns, and the fact that Aroclor 1221 is rarely reported in environmental samples, the identification of Aroclor 1221 in this area appears questionable.~~

~~Aroclor 1221 was also identified in surface sediment at four isolated locations: in the eastern nearshore zone near RM 11, in the western edge of the navigation channel near RM 10.3, in the western nearshore zone at RM 7, and in the navigation channel near RM 8. PCB congeners were analyzed at all of these stations, and in all four cases, monoCBs and diCBs were not reported at sufficient levels to support the identification of Aroclor 1221. A focused review of Aroclor chromatograms confirmed the laboratory identifications, although some differences were noted in the PCB patterns in the samples relative to the standards. The differences in PCB patterns identified by the two methods may be the result of sample heterogeneity or another unidentified cause.~~

~~Aroclor 1268 was reported in surface and subsurface sediment in the eastern nearshore zone near RM 5.6 at concentrations up to 474 J µg/kg. PCB congener profiles generally confirm the presence of Aroclor 1268. Nonachlorobiphenyls (nonaCBs) and decaCBs are present in Aroclor 1268 (Figure 5.1-34) and were more abundant in both surface sediment locations and in one of the two subsurface sediment locations analyzed in this area than in areas without Aroclor 1268 detections.~~

~~Aroclor 1268 was also identified in isolated locations in several other areas. The Aroclor 1268 identifications were confirmed by the PCB homolog profile in surface sediments in the eastern nearshore zone at RM 3.7, off the mouth of the International Terminals Slip. PCB homolog profiles did not confirm the presence of Aroclor 1268 reported in surface and subsurface samples in the eastern nearshore zone near RM 4, the surface sediments in the eastern nearshore near RM 7.3, or in the subsurface sediments in the western nearshore zone near RM 7.4. Aroclor 1268 could not be evaluated at other locations because either no PCB homolog data were available, or Aroclor 1268 constituted a relatively small fraction of the Aroclor total.~~

~~Highly chlorinated PCBs were present at one location where Aroclor 1268 was not identified. At one subsurface location (C093-B) in the International Terminals Slip, nonaCBs and decaCB together accounted for approximately 25 percent of the PCB congener total, suggesting the presence of Aroclor 1268. A review of the Aroclor chromatogram for this sample confirmed the laboratories' Aroclor identifications. Again, the differences in PCB patterns identified by the two methods may be the result of sample heterogeneity or another unidentified cause.~~

~~Aroclors 1232 and 1016 were each identified in only one sample. Aroclor 1232 was identified in subsurface sediment at location PSY36C in the navigation channel near RM 8, and Aroclor 1016 was identified in surface sediment sample PP01M105 near the east bank of Swan Island Lagoon at approximately RM 8. The unique Aroclor constituted a small fraction of the total PCB Aroclors at both locations. PCB homolog data are not available at either location to corroborate the identifications; PCB homolog data at locations near these samples do not show evidence of Aroclors 1232 or 1016. The identity of these Aroclors is questionable.~~

~~Aroclor 1262 was also identified in only one sample, a subsurface sediment sample in the navigation channel at location LW3-C760 near RM 10.5. No PCB homolog data are available at or near this location and the Aroclor identification could not be confirmed.~~ A~~ll a~~ reas where subsurface sediment concentrations exceed 1,000 ug/kg ~~all~~generally align with the locations where surface sediment concentrations are greater than 1,000 ug/kg (Maps 5.2-2a-o and 5.2-3a-ff; Figures 5.2-1~~2~~, ~~and~~ 5.2-2~~3~~ and 5.2-3~~4~~).~~,~~ ~~e~~Exceptions occur in two areas; one in the eastern nearshore zone and the other in the western nearshore zone. The eastern nearshore zone exception has elevated surface sediment concentrations ~~were elevated in the eastern nearshore area~~ from RM 6 to RM 7 where the ~~eastern nearshore~~ subsurface concentration is elevated from RM 5 to RM 6. The western nearshore exception has elevated subsurface sediment concentrations; however, surface concentrations approach~~,~~ but do not exceed~~,~~ 1,000 ug/kg.

The subsurface sediment conentrations in the downstream~~river~~ reach were greater than surface concentrations. The mean surface concentration is 34 ug/kg, while the mean subsurface concentration is 108 ug/kg.

5.2.2.5 Total PCB Sediment Relationships by River Reach

Comparisons of the total PCB data sets between the river reachs (Upriver, Downtown, Downtown exluding Zidell, Study Area and Downstream) are discussed in this section using the summary statistics tables~~,~~ and box-whisker plots~~, and Mann-Whitney test~~.

Surface Sediment

There were far more data points in the Study Area reach (1,318), than in the other river reaches (Upriver – 81; Downtown – 265; Downtown excluding Zidell – 154; and Downstream – 25) which may affect the comparability of the data sets.

The Downtown reach had the highest median of 45 ug/kg (Table 5.2-15a), followed by the Study Area reach median of 27 ug/kg (Table 5.2-1), the Downtown reach excluding Zidell median of 22 ug/kg (Table 5.2-15b), the Downstream reach median of 7 ug/kg (Table 5.2-19), and the upriver reach median of 3 J ug/kg (Table 5.2-11). These tables also show the means of the data sets result in the same order of the reaches: Downtown reach (456 ug/kg), Study Area reach (183 ug/kg), Downtown reach excluding Zidell (81 ug/kg), Downstream reach (23 ug/kg), Upriver reach (5 ug/kg).

~~Figure 5.2-5 presents a~~A box-whisker plot showing the relationship of total PCBs in sediment between the river reaches is presented in Figure 5.2-4~~5~~. The box-whisker plots were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the Upriver data set is comparatively small. The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative data in the upper range of the data set. This is also seen in the Downstream data set, and to a lesser extent in the Downtown and Downtown excluding Zidell data sets. Both the Upriver and Study Area reaches exhibit upward skewness, while all the other reaches exhibit downward skewness. It should be noted that the maximum value for the Upriver data set is a nondetect value (42 ug/kd) and the maximum detected value is 31 ug/kg. This will have an effect of skewing the data upward causing the comparisons of other data sets to this one less reliable.

~~Comparisons of data sets using box-whisker plots is done by comparing the median value of one data set with the inner quartile (i.e., box) of the other data sets. Where the median value intersects the inner quartile, those data sets are comparable; if they do not intersect, then they are not comparable.~~ Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Upriver and Study Area data sets, followed by the Downstream and Study Area, Upriver and Downtown, Downstream and Downtown, Upriver and Downtown excluding Zidell, Downstream and Downtown excluding Zidell, Downtown ~~no~~excluding Zidell and Study Area, Upriver and Downstream, and Downtown and Study Area. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

~~it can be seen that t~~The spread (i.e., inner quartile) of the U~~u~~priver ~~data set is not comparable to the Downtown reach or the Study Area reach, but is comparable~~reach overlaps the~~,~~ spread of the Downstream, ~~to the~~ Downtown reach excluding Zidell ~~data, Multnomah Channel reach,~~ and the Downstream~~river~~ reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data points for the other reachs are greater than the data points collected Upriver. There is no overlap in the Upriver or Downstream and Study Area spreads; consequently, the Study Area data set is greater than both the Upriver and Downstream data sets. The spread and medians of the Downtown reach and the Study Area reach overlap each other; hence there is no difference between these two data sets. However, while the spreads of the Downtown reach excluding Zidell and Study Area do overlap, the meadians only slightly overlap indicating that it is likely that the majority of the Study Area data is greater than the Downtown reach excluding Zidell.

Subsurface Sediment

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~~are comparable, but these reaches are not comparable with the Downtown reach or the Study Area.~~ The upriver subsurface data set is comprised of only three nondetected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. ~~However, the other reaches all have comparable data sets.~~ Like the surface sediment, the Study Area reach has far more data points (1,543) than the other reaches (Downtown – 110; Downtown excluding Zidell – 98; Downstream – 26) which may have an effect on the comparison of the data sets.

The Study Area reach had the highest median of 23 ug/kg (Table 5.2-2), followed by the Downtown reach median of 11 ug/kg (Table 5.2-16a), the Downtown reach excluding Zidell median of 7 ug/kg (Table 5.2-16b), and the Downstream reach median of 5 ug/kg (Table 5.2-20). These tables also show the means of the data sets result in the same order of the reaches: Study Area reach (282 ug/kg), Downtown reach (56 ug/kg), Downtown reach excluding Zidell (52 ug/kg), and Downstream reach (35 ug/kg).

The relative dispersion of the Downstream data set is comparatively small (Figure 5.2-4). The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative data in the upper range of the data set. Like the surface sediment plots, the whiskers on the low end are indicative of the detection limits for the data set. However, the lower bound whisker on the Study Area subsurface plot shows that extremely low detection limits were used for this data set compared to the other data sets, which would tend to skew the data downward. Further, the upper bound for this data set is due to an extremely high nondetect value (150,000 U ug/kg); the detected upper bound of 36,800 ug/kg is closer to the surface upper bound for the Study Area. This will have an effect of skewing the data upward. Consequently, the effect of double skewing this data set results in no visual skewness, but the comparisons of other data sets to this one are less reliable. Both the Downtown and Downtown excluding Zidell reaches exhibit slight upward skewness, while all the other reaches exhibit no noticable skewness.

~~The whiskers on the low end are indicative of the detection limits for the data set. The lower bound whisker on the Study Area subsurface plot shows that extremely low detection limits were used for this data set. Likewise, the upper bound for this data set is due to an extremely high nondetect value; the detected upper bound is closer to the surface upper bound for the Study Area.~~ T~~ The Upriver and Multnomah Channel data sets have comparable upper bounds and are an order of magnitude lower than the Downstreamstream data set. T~~he Downtown data set (excluding Zidell data) is an order of magnitude greater than the Downstream~~stream~~ data set and the Downtown and Study Area data sets are approximately the same at another order of magnitude higher.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually overlap all the data sets. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread and medians of the Downtown reach, Downtown reach excluding Zidell, Downriver reach, and the Study Area reach all overlap each other; hence there is no difference between these data sets.

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~~5.13.9~~5.2.3 Total PCDD/Fs and TCDD TEQ in Sediment

Dioxins and furans are being evaluated as a summed total, or total polychlorinated dibenzo dioxins/furans (total PCDD/Fs), and as a toxicity equivalent to tetra chloro dibenzo dioxin~~TCDD~~ (TCDD TEQ). The summed total value for total PCDD/Fs is merely the summed value of the measured ~~petachloro~~ homolog concentrations. However, the TCDD TEQ converts the homolog concentrations to a 2,3,7,8-TCDD equivalent by multiplying the individual congener concentrations by a factor (TEF).

~~This section discusses the nature and extent of PCDD/Fs in surface and subsurface sediment samples collected within the Study Area. Also discussed is the distribution of TCDD TEQ concentrations and observed trends in the relative abundance of PCDD/F homologs in surface and subsurface samples. TCDD toxicity with respect to 2,3,7,8-TCDD was calculated from concentrations of PCDD/F congeners designated by the WHO as similar in mechanism of toxicity to 2,3,7,8-TCDD (Van den Berg et al. 2006). Each WHO-designated congener is assigned a specific TEF indicating its degree of toxicity compared to 2,3,7,8-TCDD, which is given a reference value of 1.~~

Several data presentations for the surface and subsurface total PCDD/Fs and TCDD TEQ data sets for the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface sediment concentrations by river mile. The distribution of total PCDD/Fs and TCDD TEQ concentrations at each surface sampling station throughout the Study Area is depicted in Maps 5.2-6~~1-3~~ and 5.2-8~~1-5~~, respectively; concentrations with depth at subsurface stations are depicted in Maps 5.2-7~~1-4~~a–o~~m~~ and 5.1-9~~6~~a–o~~m~~, respectively. Detailed subsurface sediment chemicstry in the Study Area is presented on Maps 5.2-10a-l, including a key for interpreting the detailed subsurface chemistry maps.

The complete data set for total PCDD/Fs is plotted on scatter plots presented in Figures 5.2-5~~1-7~~ ~~through~~ and 5.2-6~~1-10~~. Figures 5.2-9 and 5.2-10 present scatter plots of the TCDD TEQ data set for surface and subsurface sediment in the study area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigation channel, and western nearshore zones (Map 5.2-33).

The summary statistics for total PCDD/Fs and TCDD TEQ in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total PCDD/Fs and TCDD TEQ data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detect and nondetect values. Finally a histogram presenting the average surface and subsurface sediment values for total PCDD/Fs and TCDD TEQ by river mile and for the entire Study Area is presented in Figures 5.2-7 and 5.2-11.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-37 and 5.2-38. Summary statistics for surface and subsurface sediment within the the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediemtn within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment with the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally a box-whisker plot comparing the data sets for total PCDD/Fs and TCDD TEQ in the Upriver reach, Downtown reach, Study Area reach, and Downstream reach are presented in Figures 5.2-8 and 5.2-12.

5.2.3.1 Total PCDD/Fs and TCDD TEQ Data Sets

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The ~~selection~~ number of sediment samples for PCDD/F analysis wa~~i~~s typically based on a highly biased approach at locations near known or suspected sources. As a result, there are relatively fewer data points for these analytes and the resulting TCDD TEQ data in the RI sediment database than for other chemicals (for example, the PCDD/F data set is approximately one-fifth the size of the PCBs and DDx data sets). This is particularly true in areas away from suspected sources, such as the navigation channel.

The existing PCDD/F data are sufficient for RI purposes; however, as will be pointed out in this section and later in Section 10, the fewer number of data points for total PCDD/Fs in some areas limits the level of detail to which the extent of chemical distribution may be resolved, and introduces the need for caution in interpreting the surface to subsurface trends shown by the histograms (Figures 5.2-7 and 5.2-11~~Section 5.1.6.5~~) and in making conclusions regarding the spatial patterns of the composition of total PCDD/Fs and TCDD TEQ in sediment (Sections 5.2.3.2 through 5.2.3.5~~1.6.6~~). Total PCDD/Fs data for sediment within the Study Area are available for 237 surface and 327 subsurface samples; there are 238 surface and 331 subsurface samples in the Study Area sediment TCDD TEQ data set.

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~~5.13.9.1~~5.2.3.2 Total PCDD/Fs in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total PCDD/Fs were analyzed in 39 surface sediment samples and detected in 38 samples within the Upriver reach (detection frequency of 97 percent), with detected concentrations ranging from 2.39 pg/g (0.00239 ug/kg) to 733 pg/g (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that there are 12 data points between 100 and 1,000 pg/g. The majority of the detected data set (17 samples; 45 percent) is comprised of concentrations ranging between 10 and 100 pg/g. Another 9 samples, or 24 percent of the detected data set, was detected at a concentration between 1 and 10 pg/g. The mean total PCDD/Fs concentration in this reach is 90 pg/g.

Downtown Reach (RM 11.8 to 15.3)

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Total PCDD/Fs were analyzed in 67 surface sediment samples and detected in 62 samples within the Downtown reach (detection frequency of 93 percent), with detected concentrations ranging from 9.45 J pg/g to 15,400 J pg/g (Table 5.2-15a) and a mean concentration of 1,130 pg/g. Total PCDD/Fs concentrations in surface sediment varied along the Downtown reach (Map 5.2-37). The map shows that the majority of the samples with highest concentrations are located along the eastern shoreline.

Tables 5.2-17 and 5.2-18 show that there is 1 data point greater than 10,000 pg/g. There are 17 detected values between 1,000 and 10,000 pg/g. An addional 26 samples, 42 percent of the detected data set, were detected at concentrations between 100 and 1,000 pg/g. Another 16 samples, 26 percent of the detected data set, were detected at concentrations ranging between 10 and 100 ug/kg. Only 2 samples, or 3 percent of the detected data set, are between 1 and 10 pg/g and no samples were detected at a concentration less than 1 pg/g.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the total PCDD/Fs data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Total PCDD/Fs were detected in all 237~~16~~ surface sediment samples in which this suite of chemicals was analyzed. ~~–~~Surface concentrations ranged from 2.48 to 264,000 pg/g (Table 5.2~~1~~-1), with a mean concentration of 2,407 pg/g. ~~Ninety-five percent of the surface data was below 5,620 JV pg/g.~~ Total PCDD/Fs concentrations in surface sediment varied along the Study Area (Figure 5.2-5). Total PCDD/Fs concentrations exceeding 2,000 pg/g in the scatter plots are indicated in red on Map 5.2-6.

A substantial portion of the eastern nearshore zone (RM 2 through 8) has concentrations exceeding 1,000 pg/g, as well as Swan Island Lagoon and RM 11. Mean concentrations (see Table 5.2-3) for these areas in the eastern nearshore zone are: 1,170 pg/g for RM 3 to 4; 1,640 pg/g for RM 4 to 5; 1,300 pg/g for RM 5 to 6; 3,440 pg/g for RM 6 to 7; 1,510 pg/g for RM 7 to 8; 3,030 pg/g for Swan Island Lagoon; and 1,510 pg/g for RM 11 to 11.8.

There are also prominent peaks exceeding 1,000 pg/g in the western nearshore zone from RM 6 to 10 with less promenant peaks present from RM 4 to 6. Mean concentrations (see Table 5.2-7) for these areas in the western nearshore zone are: 726 pg/g for RM 4 to 5; 830 pg/g for RM 5 to 6; 1,730 pg/g for RM 6 to 7; 15,200 pg/g for RM 7 to 8; 1,500 pg/g for RM 8 to 9; and 1,690 pg/g for RM 9-10. The highest surface sediment concentration (264,000 pg/g) in the data set was detected between RM 7 and 8.

There were two prominent peaks in the navigation channel zone; one from RM 6 to 7 and the other from RM 11 to 11.8. Reviewing the data on Map 5.2-6, it appears that these peaks are associated with the peaks in the eastern nearshore zone rather than indicative of the entire navigation channel containing elevated concentrations. The maximum concentrations in these areas are: 2,260 pg/g for RM 6 to 7 and 2,020 pg/g for RM 11 to 11.8. The associated mean concentrations for these areas are: 779 pg/g for RM 6 to 7 and 810 pg/g for RM 11 to 11.8 (Table 5.2-5).

Tables 5.2-9 and 5.2-10 show that there are only 7 data points greater than 10,000 pg/g. There are 27 detected values between 1,000 and 10,000 pg/g, which are within the prominent peaks described above. Surface sediment concentrations greater than 1,000 pg/g accounts for 30 perent of the detected data set (Map 5.2-6). Over half the detected data set (133 samples; 56 percent) is comprised of samples ranging from 100 to 1,000 pg/g. Another 31 samples, or 13 percent, a~~we~~re detected at concentrations between 10 and 100 pg/g and only three samples, or 1 percent, were detected at concentrations ranging from 1 to 10 pg/g.

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The data show concentrations greater than 2,000 pg/g (indicated in red on Map 5.2-6~~1-3~~) total PCDD/Fs at several locations along the eastern and western nearshore zones. Limited surface PCDD/F data are available for the navigation channel and spatial resolution is somewhat limited. However, of the channel samples that were analyzed, most concentrations were less than 500 pg/g, except as noted above, and a pattern is evident of relatively high concentrations in nearshore areas compared with markedly lower levels in the adjacent channel areas.

Downstream Reach (RM 0 to 1.9)

Total PCDD/Fs were analyzed and detected in all 21 samples within the Downstream reach, with concentrations ranging from 1.56 J pg/g to 1,780 J pg/g (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there ~~is~~are only 3 data points greater than 1,000 pg/g. An additional 8 samples, 38 percent of the detected data set, were detected at concentrations between 100 and 1,000 pg/g. Over half the detected data set (11 samples; 52 percent) is comprised of concentrations ranging between 1 and 10 pg/g and no samples were detected at concentrations less than 1 pg/g. The mean total PCDD/Fs concentration in this reach is 232 pg/g.

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~~5.13.9.2~~5.2.3.3 Total PCDD/Fs in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total PCDD/Fs were analyzed and detected in 3 subsurface sediment samples within the Upriver reach (detection frequency of 100 percent), with detected concentrations ranging from 3.59 pg/g to 1,090 pg/g (Table 5.2-12). Tables 5.2-13 and 5.2-14 show that there is one data point between 1,000 and 10,000 pg/g and two data points between 100 and 1,000 pg/g. The mean total PCDD/Fs concentration in this reach is 816 pg/g.

Downtown Reach (RM 11.8 to 15.3)

Total PCDD/Fs were analyzed in 44 subsurface sediment samples and detected in 39 samples within the Downtown reach (detection frequency of 89 percent), with detected concentrations ranging from 4.74 pg/g to 4,590 J pg/g (Table 5.2-15a) and a mean concentration of 1,090 pg/g.

Tables 5.2-17 and 5.2-18 show that there are 17 detected values between 1,000 and 10,000 pg/g. An addional 11 samples, 28 percent of the detected data set, were detected at concentrations between 100 and 1,000 pg/g. Another 8 samples, 21 percent of the detected data set, were detected at concentrations ranging between 10 and 100 ug/kg. Only 3 samples, or 8 percent of the detected data set, are between 1 and 10 pg/g and no samples were detected at a concentration less than 1 pg/g.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the Downtown data set. None of the total PCDD/Fs data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Total PCDD/Fs were detected in 325 of the 327 subsurface samples analyzed within the Study Area (detection frequency of 99 percent), with concentrations ranging from 0.0578 J pg/g to 425,000 J pg/g and a mean concentration of 9,052 pg/g (Table 5.2-2). Similar to surface sediment, total PCDD/Fs concentrations in the subsurface also varied within the Study Area (Figure 5.2-6; Maps 5.2-4a-o).

~~Of the 241 subsurface samples analyzed, total PCDD/Fs were detected in all but one of the samples. Concentrations ranged from 0.0578 J pg/g to 218,000 pg/g (Table 5.1-2).~~

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The greatest total PCDD/F concentrations (>10,000 pg/g) are seen in the eastern nearshore zone from RM 6 to 7, in Swan Island Lagoon, and from RM 11 to 11.8 (Figure 5.2-6). Concentrations greater than 1,000 pg/g in subsurface sediment are prevalent throughout the site, especially in the eastern nearshore zone from RM 2 through 8 and RM 11 to 11.8. Mean concentration (see Table 5.2-4) for these areas in the eastern nearshore zone are: 446 pg/g for RM 1.9 to 3; 638 pg/g for RM 3 to 4; 1,340 pg/g for RM 4 to 5; 561 for RM 5 to 6; 1,650 pg/g for RM 6 to 7; 19,500 pg/g for RM 7 to 8; 981 pg/g in Swan Island Lagoon; and 1,510 pg/g from RM 11 to 11.8.

There are also areas in the western nearshore zone between RM 6 and 8 that exceed 10,000 pg/g (Figure 5.2-6). Concentrations greater than 1~~2~~,000 pg/g are also seen in subsurface sediment in the western nearshore zone from RM 4 through 11. Core sample C455 (30–152 cm bml) collected along the western shoreline at RM 8.8 contained the highest subsurface concentration of total PCDD/Fs in the data set (Table 5.2-6). Mean concentrations for these areas in the western nearshore zone are: 287 pg/g for RM 4 to 5; 33 pg/g for RM 5 to 6; 375 pg/g for RM 6 to 7; 2,270 for RM 7 to 8; 19,400 pg/g for RM 8 to 9; 269 pg/g for RM 9 to 10.

Limited subsurface total PCDD/F data are available for the navigation channel; of the samples that were analyzed, most concentrations were less than 100 pg/g. Concentration greater than 1,000 are only seen in the navigation channel from RM 6 to 7 and RM 11 to 11.8 and appear to be related to the contamination in the eastern nearshore zone (Maps 5.2-7~~4~~a-o). Elevated concentrations in the subsurface samples ~~were~~ are generally found at the same surface locations with PCDD/F concentrations greater than 1~~2~~,000 pg/g along the eastern and western nearshore zones (Maps 5.2~~1~~-7~~4~~a–o~~m~~).

Tables 5.2-9 and 5.2-10 show that there are only 26 data points greater than 10,000 pg/g. There are 71 detected values between 1,000 and 10,000 pg/g, which are within the elevated concentration areas described above. Subsurface sediment concentrations greater than 1,000 pg/g account for 30 perent of the detected data set. An additional 103 samples (32 percent of the detected data set) is comprised of samples ranging from 100 to 1,000 pg/g. Another 74 samples, or 23 percent, are detected at concentrations between 10 and 100 pg/g. Only 31 samples, or 10 percent, were detected at concentrations ranging from 1 to 10 pg/g and 20 samples, or 6 percent, were detected at concentrations less than 1 pg/g.

Downstream Reach (RM 0 to 1.9)

Total PCDD/Fs were analyzed and detected in all 17 samples within the Downstream reach, with concentrations ranging from 0.093 pg/g to 967 pg/g (Table 5.2-20). Tables 5.2-21 and 5.2-22 show that there are 5 data points greater than 100 pg/g (29 percent of the detected data set). An additional 7 samples, 41 percent of the detected data set, were detected at concentrations between 10 and 100 pg/g. Another 2 samples (12 percent) is comprised of concentrations ranging between 1 and 10 pg/g and 3 samples (18 percent) were detected at concentrations less than 1 pg/g. The mean total PCDD/Fs concentration in this reach is 145 pg/g.~~Core sample C455 (30–152 cm bml) collected along the western shoreline at RM 8.8 contained the highest subsurface concentration of total PCDD/Fs in the data set (Table 5.1-2). This station also contained the maximum total PCBs and total chlordanes concentrations in the Study Area.~~

~~Limited subsurface PCDD/F data are available for the navigation channel; of the samples that were analyzed, most concentrations were less than 100 pg/g (Maps 5.1-4a-m).~~

5.2.3.4 TCDD TEQ in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

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TCDD TEQ were analyzed in 49 surface sediment samples and detected in 48 samples within the Upriver reach (detection frequency of 98 percent), with detected concentrations ranging from 0.00684 J pg/g to 2.99 pg/g (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that there are 3 data points between 1 and 10 pg/g. The majority of the detected data set (42 samples; 88 percent) is comprised of concentrations less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 0.3 pg/g.

~~**5.13.9.3** ***Downtown Reach (RM 11.8 to 15.3)***~~

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Downtown Reach (RM 11.8 to 15.3)

TCDD TEQ were analyzed in 67 surface sediment samples and detected in 63 samples within the Downtown reach (detection frequency of 94 percent), with detected concentrations ranging from 0.011 J pg/g to 19 J pg/g (Table 5.2-15a) and a mean concentration of 2.6 pg/g. TCDD TEQ concentrations in surface sediment varied along the Downtown reach (Map 5.2-38).

Tables 5.2-17 and 5.2-18 show that there are 2 data points between 10 and 100 pg/g. There are 35 detected values (56 percent) between 1 and 10 pg/g. An addional 26 samples, 41 percent of the detected data set, are detected at concentrations less than 1 pg/g.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the TCDD TEQ data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

TCDD TEQ ~~are~~was detected in all 238 surface sediment samples in which this suite of chemicals was analyzed. Surface concentrations ranged from 0.008 J to 14,100 J pg/g, with a mean concentration of 68 pg/g (Table 5.2-1). TCDD TEQ concentrations in surface sediment varied along the Study Area (Figure 5.2-9). TCDD TEQ concentrations exceeding 10 pg/g in the scatter plots are indicated in red on Map 5.2-6.

The eastern nearshore zone has concentrations exceeding 10 pg/g from RM 6 through 8, in Swan Island Lagoon, and from RM 11 to 11.8. Mean concentrations (see Table 5.2-3) for these areas in the eastern nearshore zone are: 16 pg/g for RM 6 to 7; 12 pg/g for RM 7 to 8; 4.9 pg/g for Swan Island Lagoon; and 4.4 pg/g for RM 11 to 11.8.

There are also prominent peaks exceeding 10 pg/g in the western nearshore zone from RM 6 to 10. Mean concentrations (see Table 5.2-7) for these areas in the western nearshore zone are: 20 pg/g for RM 6 to 7; 79 pg/g for RM 7 to 8; 3.6 pg/g for RM 8 to 9; and 4.6 pg/g for RM 9 to 10. The highest surface sediment concentration (14,100 pg/g) in the data set was detected between RM 7 and 8. There were no concentrations measured in the navigation channel zone above 10 pg/g.

Tables 5.2-9 and 5.2-10 show that there is only 1 data point greater than 10,000 pg/g. There are no detected values between 1,000 and 10,000 pg/g and 4 samples (2 percent of the detected data set) detected at concentrations between 100 and 1,000 pg/g. An additonal 28 samples, or 12 percent, are detected at concentrations ranging between 10 and 100. Approximately half the detected data set (107 samples; 45 percent) is comprised of samples ranging from 1 to 10 pg/g. Another 98 samples, or 41 percent, are detected at concentrations less than 1 pg/g.

~~A total of 217 surface samples were selected for analysis of WHO-designated PCDD/Fs, with a frequency of detection of 100 percent. The resulting calculated TCDD TEQs show a wide range of values, from 0.00803 J pg/g to 14,100 J pg/g in surface sediment (Table 5.1-1). Ninety-five percent of the surface data were below 43.2 JV pg/g.~~

The data show that TCDD TEQ values vary spatially along the length of the Study Area (Figure 5.2~~1~~-9). In general, values were higher in the western nearshore zone than in the eastern nearshore and navigation channel zones. The most significant peak in the data in the western nearshore occurred between approximately RM 6.8 and 7.3, where data points are relatively dense in comparison to the rest of the Study Area.

Limited data for ~~WHO-designated PCDD/Fs~~TCDD TEQ are available for sediments in the navigation channel (Map 5.2~~1~~-8~~5~~). TCDD TEQ surface values within the channel were relatively low, with the exception of two samples with relatively elevated concentrations along the eastern edge of the navigation channel between RM 6.6 and 6.7.

Downstream Reach (RM 0 to 1.9)

TCDD TEQ were analyzed and detected in all 21 samples within the Downstream reach, with concentrations ranging from 0.0051 J pg/g to 2.6 J pg/g (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there are only 2 data points with concentrations ranging between 1 and 10 pg/g. The majority of the data set (19 samples; 90 percent) were detected at concentrations less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 0.4 pg/g.

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~~5.13.9.4~~5.2.3.5 TCDD TEQ in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

TCDD TEQ were analyzed and detected in 3 subsurface sediment samples within the Upriver reach (detection frequency of 100 percent), with detected concentrations ranging from 0.66 pg/g to 2.63 pg/g (Table 5.2-12). Tables 5.2-13 and 5.2-14 show that there is one data point between 1 and 10 pg/g and two data points less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 2 pg/g.

Downtown Reach (RM 11.8 to 15.3)

TCDD TEQ were analyzed in 44 subsurface sediment samples and detected in 41 samples within the Downtown reach (detection frequency of 93 percent), with detected concentrations ranging from 0.0023 J pg/g to 13 pg/g (Table 5.2-15a) and a mean concentration of 2.7 pg/g.

Tables 5.2-17 and 5.2-18 show that there is one detected values between 10 and 100 pg/g. An addional 24 samples, 59 percent of the detected data set, were detected at concentrations between 1 and 10 pg/g. Another 16 samples, 39 percent of the detected data set, were detected at concentrations less than 1 pg/g.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the Downtown data set. None of the TCDD TEQ data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

TCDD TEQ were analyzed in 331 subsurface sediment samples within the Study Area and detected in 238 samples (detection frequency of 95 percent), with concentrations ranging from 0.0003 J to 24,400 J pg/g and a mean concentration of 433 pg/g (Table 5.2-2). TCDD TEQ concentrations in subsurface sediment varied along the Study Area (Figure 5.2-10). TCDD TEQ concentrations exceeding 10 pg/g in the scatter plots are indicated in red on Maps 5.2-9a-o and 5.2-10a-l.

The eastern nearshore zone has concentrations exceeding 10 pg/g from RM 6 through 8 and from RM 11 to 11.8. Mean concentrations (see Table 5.2-4) for these areas in the eastern nearshore zone are: 5.8 pg/g for RM 6 to 7; 38 pg/g for RM 7 to 8; and 7.7 pg/g for RM 11 to 11.8.

There are also concentrations exceeding 10 pg/g in the western nearshore zone from RM 4 ~~to 5 and RM 6~~ through 9, with a prominent peak from RM 6.5 to 7.5. Mean concentrations (see Table 5.2-8) for these areas in the western nearshore zone are: 5.3~~2.8~~ pg/g for RM 4 to 5; 2.5 pg/g for RM 5 to 6; 20~~5.9~~ pg/g for RM 6 to 7; 73~~??~~ pg/g for RM 7 to 8; and 37~~5.7~~ pg/g for RM 8 to 9. The highest surface sediment concentration (24,400 pg/g TCDD TEQ) in the data set was detected between RM 6.5 and 7.5. The maximum subsurface TCDD TEQ value was found at Station SD092 (0–90 cm vertically composited sample) at RM 7.2W (Map 5.2-9h).

Limited subsurface TCDD TEQ data are available for the navigation channel; of the samples that were analyzed, most concentrations were less than 10 pg/g. Concentrations greater than 10 are only seen in the navigation channel from RM 6 to 7 and appear to be related to the contamination in the western nearshore zone (Maps 5.2-9a-o and 5.2-10a-l). Elevated concentrations in the subsurface samples are generally found at the same surface locations with TCDD TEQ concentrations greater than 10 pg/g along the eastern and western nearshore zones (Maps 5.2-9a–o and 5.2-10a-l).

Tables 5.2-9 and 5.2-10 show that there are 3 data points greater than 10,000 pg/g. There are 14 detected values between 1,000 and 10,000 pg/g and 12 samples detected at concentrations between 100 and 1,000 pg/g. An additonal 42 samples are detected at concentrations ranging between 10 and 100. Another 99 samples, or 32 percent, are detected at concentrations between 1 and 10 pg/g. Approximately half the detected data set (143 samples; 46 percent) is comprised of sample concentrations less than 1 pg/g.

The data show that TCDD TEQ values vary spatially along the length of the Study Area (Figure 5.2-10). In general, values were higher in the western nearshore zone than in the eastern nearshore and navigation channel zones. The most significant peak in the data in the western nearshore occurred between approximately RM 6.8 and 7.3, where data points are relatively dense in comparison to the rest of the Study Area.

Limited data for TCDD TEQ are available for sediments in the navigation channel (Map 5.2-8). TCDD TEQ surface values within the channel were relatively low, with the exception of one sample with relatively elevated concentrations

~~WHO-designated PCDD/Fs were detected in approximately 93 percent of the 245 subsurface samples in which they were analyzed. The resulting calculated TEQs show a wide range of values, from an estimated 0.000262 J pg/g to an estimated 7,480 J pg/g in subsurface sediment (Table 5.1-2; Figure 5.1-10).~~

~~The maximum subsurface TCDD TEQ value was found at Station SD092 (0–90 cm vertically composited sample) at RM 7.2W (Map 5.1-6h).~~

~~Within the navigation channel, TCDD TEQ values over 10 pg/g (indicated in red in Maps 5.1-6a-m) were calculated only at one subsurface station~~ near the western channel boundary at RM 6.6 (33.3 J pg/g in the interval from 132 to 243 cm bml at Station C314; Figure 5.2~~1~~-10).

Downstream Reach (RM 0 to 1.9)

TCDD TEQ were analyzed in 17 sampleswithin the Downstream reach and detected in 16 samples (dection frequency of 94 percent), with concentrations ranging from 0.003 pg/g to 1.5 J pg/g (Table 5.2-20). Tables 5.2-21 and 5.2-22 show that there is only one data point with concentrations ranging between 1 and 10 pg/g. The majority of the data set (15 samples; 94 percent) were detected at concentrations less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 0.26 pg/g.

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~~5.13.9.5~~5.2.3.6 Total PCDD/F and TCDD TEQ Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination.

The surface total PCDD/Fs sediment concentrations in the downtown reach are slightly higher than the subsurface concentrations while the TCDD TEQ concentrations are approximately the same. The mean surface total PCDD/Fs concentration is 1,130 pg/g and the subsurface concentration is 1,090 pg/g. The surface TCDD TEQ concentration is 2.6 pg/g while the subsurface sediment concentration is 2.7 pg/g.

Total PCDD/Fs and TCDD TEQ concentrations are generally greater in the subsurface sediments than in surface sediments within the Study Area as a whole. The mean total PCDD/Fs surface sediment concentration is 2,407 pg/g and the subsurface concentration is 9,052 pg/g; the mean total TCDD TEQ surface sediment concentration is 68 pg/g and the subsurface concentration is 434 pg/g. Most areas throughout the Study Area reach lack a strong or consistent vertical concentration gradient. This pattern may be due to the lack of samples and is supported by Maps 5.2-10a-l.

~~The magnitude of the mean surface and subsurface sediment concentrations for PCDD/Fs is shown on Figure 5.1-39. Summary statistics are presented in Table 5.1-4. The methods used to develop these presentations are described in Section 5.1.5.4. It should be noted that fewer data points are available for PCDD/Fs than for the other bounding chemical groups (PCBs, DDx, and PAHs). This relatively small sample size combined with the effect on the mean of one or two elevated values in a given subarea limits the interpretability of Figure 5.1-39; the actual mapped data patterns shown in Maps 5.1-4a-m are also discussed here.~~

~~The surface/subsurface mean ratios show that total PCDD/F concentrations were slightly higher in surface sediments within the Study Area overall (left side of Figure 5.1-39), but the magnitude of the ratios are small, indicating that the average surface and subsurface concentrations were comparable across most of the Study Area. This pattern is supported by Maps 5.1-4a–m, which show that most areas lack strong or consistent vertical concentration gradients.~~ Some exceptions to this include the area under and just upstream of the Railroad Bridge at RM 6.9, where surface layers show higher concentrations than at depth (Map 5.2~~1~~-10~~4~~g) and the northwest corner of Willbridge Terminal where higher levels are evident at depth (Map 5.2~~1~~-10~~4~~h). This suggests a current source or sources at the former location and an historical source or sources at the latter. Elsewhere in the Study Area, significant changes in the level of PCDD/F inputs over time are generally not indicated by the data collected.

~~5.13.9.6 Patterns and Trends of PCDD/Fs in Sediment~~

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~~PCDD/F homolog compositions for samples within the Study Area are presented as bar charts in Figures 5.1-40a–c and 5.1-41a–c. The bar charts show the percent composition of the individual PCDD/F homologs for each sample. The figures are organized to show the east zone, navigation channel, and west zone (relative to the navigation channel boundary). Subsurface homolog patterns are shown only for the depth interval with the highest total PCDD/F concentration at each location. The PCDD/F composition at other depths may differ from that at the depth of maximum concentration.~~

~~OCDD is generally the dominant homolog (>50 percent of the total concentration) present in surface and subsurface sediments throughout the Study Area, with HpCDDs present to a significant but lesser degree. The other homolog groups generally constitute 20 percent or less of the total concentration. Exceptions where PCDD/F homolog distributions appear to vary significantly (possibly reflecting isolated areas of differing sources or weathering patterns) are clustered throughout the Study Area, with the largest clusters occurring along the western nearshore area around RM 6.8 and near RM 7.4, where data points are relatively dense in comparison to the rest of the Study Area.~~

~~The apparent variations in PCDD/F homolog compositions do not always reflect variations in total PCDD/F concentrations. Near RM 6.7E and from RM 6.8 to 7.4W, samples with high total PCDD/F concentrations are marked by a high proportion of furans relative to other areas. However, in general, samples with high PCDD/F concentrations have homolog profiles that match the prevailing pattern of OCDD and HpCDD dominance. Also, the surface and subsurface homolog distributions did not appear to vary greatly for any given location.~~

~~Finally, and as noted previously, definitive statements about spatial patterns in PCDD/F composition cannot be made based on the stacked bar charts, particularly for PCDD/Fs,~~

~~which were analyzed based on a highly biased sampling design; this was not a primary goal of the RI sampling program. Detailed forensic analyses would be required to determine the existence of statistically significant patterns in the data.~~ The surface total PCDD/Fs sediment concentrations in the downstream reach are slightly higher than the subsurface concentrations while the TCDD TEQ concentrations are approximately the same. The mean surface total PCDD/Fs concentration is 232 pg/g and the subsurface concentration is 67 pg/g. The surface TCDD TEQ concentration is 0.4 pg/g while the subsurface sediment concentration is 0.3 pg/g.

5.2.3.7 Total PCDD/Fs and TCDD TEQ Sediment Relationships by River Reach

Comparisons of the total PCDD/Fs and TCDD TEQ data sets between the river reachs (Upriver, Downtown, Downtown exluding Zidell, Study Area and Downstream) are discussed in this section using the summary statistics tables and box-whisker plots.

Surface Sediment

There were far more data points in the Study Area reach (237 for total PCDD/Fs; 238 for TCDD TEQ), than in the other river reaches (Upriver – 39 for total PCDD/FS and 49 for TCDD TEQ; Downtown – 67 for both total PCDD/Fs and TCDD TEQ; and Downstream – 21 for both total PCDD/Fs and TCDD TEQ) which may affect the comparability of the data sets.

The Downtown reach had the highest total PCDD/Fs median of 444 J pg/g (Table 5.2-15a), followed by the Study Area reach median of 412 pg/g (Table 5.2-1), the Downstream reach median of 77 pg/g (Table 5.2-19), and the upriver reach median of 59 J pg/g (Table 5.2-11). These tables also show the means of the total PCDD/Fs data sets result in a different order of the reaches: Study Area (2407 pg/g), Downtown reach (1130 pg/g); Downstream reach (232 pg/g), and Upriver reach (90 pg/g).

For TCDD TEQ these tables show a slightly different pattern for the medians than total PCDD/Fs. The Downtown and Study Area reach TCDD TEQ medians are the same (1.4 J pg/g), followed by the Downstream reach (0.16 J pg/g) and the Upriver reach (0.16 J pg/g). The means, however, follow the same pattern as the total PCDD/Fs data: Study Area reach (68 pg/g); Downtown reach (2.6 pg/g); Downstream reach (0.4 pg/g); and Upstream reach (0.3 pg/g).

A box-whisker plot showing the relationship of total PCDD/Fs and TCDD TEQ in sediment between the river reaches is presented in Figure 5.2-8. The box-whisker plots were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the ~~Upriver~~Upriver data set is comparatively small. The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative data in the upper range of the data set. This is also seen in the Downstream data

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set, and to a lesser extent in the Downtown ~~and Downtown excluding Zidell~~ data set~~s~~. ~~Both t~~The ~~Upriver and~~ Study Area reache~~s~~ exhibit~~s~~ down~~up~~ward skewness, while all the other reaches exhibit up~~down~~ward skewness. ~~It should be noted that the maximum value for the Upriver data set is a nondetect value (42 ug/kd) and the maximum detected value is 31 ug/kg. This will have an effect of skewing the data upward causing the comparisons of other data sets to this one less reliable.~~

Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Upriver and Study Area data sets, followed by the Downstream and Study Area, Upriver and Downtown, ~~Downstream and Downtown, Upriver and Downtown excluding Zidell, Downstream and Downtown excluding Zidell, Downtown no Zidell and Study Area,~~ Upriver and Downstream, and Downtown and Study Area. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) of the Upriver reach overlaps the spread of the Downstream~~, Downtown reach excluding Zidell~~ and the Downstream reach; however, the median of the Downtown reach~~s~~ ~~-~~does not overlap the spread of the Upriver and Downstream reaches. Thus, it is likely that the majority of the data points for the ~~other~~Downtown reach~~s~~ ~~are~~is greater than the data points collected Upriver and Downstream. There is no overlap in the Upriver or Downstream and Study Area spreads; consequently, the Study Area data set is greater than both the Upriver and Downstream data sets. The spread and medians of the Downtown reach and the Study Area reach overlap each other; hence there is no difference between these two data sets. ~~However, while the spreads of the Downtown reach excluding Zidell and Study Area do overlap, the meadians only slightly overlap indicating that it is likely that the majority of the Study Area data is greater than the Downtown reach excluding Zidell.~~

Subsurface Sediment

The upriver subsurface data set is comprised of only three detected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like the surface sediment, the Study Area reach has far more data points (327 for total PCDD/Fs and 331 for TCDD TEQ) than the other reaches (Downtown – 44 for both total PCDD/Fs and TCDD TEQ; and Downstream – 17 for both total PCDD/Fs and TCDD TEQ) which may have an effect on the comparison of the data sets.

The Upriver reach had the highest median of 1,000 pg/g (Table 5.2-12), followed by the Downtown reach median of 541 JA pg/g (Table 5.2-16a), the Study Area reach median of 290 pg/g (Table 5.2-2), and the Downstream reach median of 59 J pg/g (Table 5.2-20). These tables also show the means of the data sets result in a different order of the reaches: Study Area reach (9,052 pg/g), Downtown reach (1,090 pg/g), Upriver reach (816 pg/g), and Downstream reach (145 pg/g).

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For TCDD TEQ these tables show a slightly different pattern for the medians than total PCDD/Fs. The Downtown reach had the highest median (1.6 J pg/g), followed by the Study Area and Upriver reach (1.4 J pg/g), and the Downstream reach (0.1 J pg/g). The means, however, follow the same pattern as the total PCDD/Fs data: Study Area reach (434 pg/g); Downtown reach (2.7 pg/g); Upriver reach (1.6 pg/g); and Downstream reach (0.2 pg/g).

A box-whisker plot showing the relationship of total PCDD/Fs and TCDD TEQ in sediment between the river reaches is presented in Figure 5.2-12. The box-whisker plots were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set.

The relative dispersion of the ~~Downstream~~Upstream data set is comparatively small, due to the small number of data points (i.e., three). The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative data in the upper range of the data set. Like the surface sediment plots, the whiskers on the low end are indicative of the detection limits for the data set. However, the lower bound whisker on the Study Area and Downstream subsurface plots show~~s~~ that extremely low detection limits were used for the~~is~~se data set compared to the other data sets, which would tend to skew the data downward. ~~Further, the upper bound for this data set is due to an extremely high nondetect value (150,000 U ug/kg); the detected upper bound of 36,800 ug/kg is closer to the surface upper bound for the Study Area.~~ This will ~~have an effect of skewing the data upward. Consequently, the effect of double skewing this data set results in no visual skewness, but~~result in the comparisons of other data sets to this one are less reliable. Both the ~~Downtown~~Downstream and Downtown ~~excluding Zidell~~ reaches exhibit slight upward skewness, while all the other reaches exhibit no noticable skewness. The ~~Downtown~~Study Area data set ~~(excluding Zidell data),~~ is ~~an~~two orders of magnitude greater than the ~~Downstream~~the other data sets~~ and the Downtown and Study Area data sets are approximately the same at another order of magnitude higher~~.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually overlap all the data sets. The spread and medians of the Downtown reach, Upriver reach, and the Study Area reach all overlap each other; hence there is no difference between these data sets. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

~~The spread and medians of the Downtown reach, Downtown reach excluding Zidell, Downriver reach, and the Study Area reach all overlap each other; hence there is no difference between these data sets.~~

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~~5.13.11~~5.2.4 Total DDx in Sediment

Several data presentations for the surface and subsurface total DDx data set within the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. The distribution of total DDx concentrations at each surface sediment sampling station throughout the Study Area is depticted on Map 5.2-11; concentrations with depth at subsurface stations are depicted on Maps 5.2-12a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented. Detailed subsurface sediment chemistry in the Study Area is presented on Maps 5.2-13a-gg, including a key for interpreting the detailed subsurface chemistry maps.

Figures 5.2-13 and 5.2-14 present scatter plots of the total DDx data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for total DDx in the surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigational channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total DDx data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detect and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-15.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-39. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-6; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-16.

The individual total DDT, DDD, and DDE concentrations (totals of the 2,4'- and 4,4'-isomers) are depicted in similar maps, tables and figures as total DDx in Appendix D1.

5.2.4.1 Total DDx Data Set

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Total DDx is the sum of the total DDT (calculated as the sum of the 2,4'-DDT and 4,4'-DDT isomers), total DDD (calculated as the sum of the 2,4'-DDD and 4,4'-DDD isomers), and total DDE (calculated as the sum of the 2,4'-DDE and 4,4'-DDE isomers) concentrations. ~~The distribution of concentrations of total DDx and its constituent compounds DDD, DDT, DDE in the Study Area sediment is summarized in this section. Observed trends in DDx isomers in surface and subsurface samples are also discussed. Frequencies of detection of total DDx were approximately 89 percent for surface samples and 81 percent for subsurface samples.~~

~~The distribution of total DDx concentrations at each surface sampling station throughout the Study Area is depicted in Map 5.1-7; concentrations with depth at subsurface stations are depicted in Maps 5.1-8a–m. The complete data set is plotted on scatter plots presented in Figures 5.1-11 and 5.1-12. The individual total DDT, DDD, and DDE concentrations (totals of the 2,4'- and 4,4'-isomers) are depicted in Maps D1.1-3 through D1.1-8 in Appendix D1.1.~~

Some of the results of the component isomers that were summed in the total DDx concentrations were N-qualified ~~(Section 2.1.3.2)~~. Additionally, some of the DDx isomer data are uncertain and potentially biased high because of the analytical interference from the presence of PCB congeners in the sample. The N qualifier indicates that the quantity is estimated because there is only presumptive evidence that the chemical compound exists. When an individual isomer result is N-qualified, the N qualifier is carried forward to the reported summed total. For individual isomers, the percentages of N-qualified sediment data range from zero (2,4'-DDE) to approximately 30 percent (2,4'-DDD) of both the surface and subsurface data. N-qualified total DDx concentrations range from 0.051 NJ µg/kg to 84,900 NJ µg/kg in surface sediment and from 0.054 NJ µg/kg to 51,800 NJ µg/kg in subsurface sediment.

~~5.13.11.1~~5.2.4.2 Total DDx in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

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Total DDx were analyzed in 81 surface sediment samples and detected in 56 samples within the Upriver reach (detection frequency of 69 percent), with detected concentrations ranging from 0.09 J ug/kg to 15 JA ug/kg (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that there is one data point greater than 10 ug/kg. The majority of the detected data set (73 percent) is comprised of concentrations ranging between 1 and 10 ug/kg. Another 14 samples, or 25 percent of the detected data set, was detected at a concentration less than 1 ug/kg. the mean total DDx concentration in this reach is 2 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

Total DDx were analyzed in 149 surface sediment samples and detected in 130 samples within the Downtown reach (detection frequency of 87 percent), with detected concentrations ranging from 0.05 J ug/kg to 73 J ug/kg (Table 5.2-15a) and a mean concentration of 6.6 ug/kg. Total DDx concentration in surface sediment varied along the Downtown reach (Map 5.2-39). The map shows that the majority of the samples with the highest concentrations (depicted as green dots on the map) are clusted together in localized areas rather than dispersed throughout the site.

Tables 5.2-17 and 5.2-18 show that there are 25 data points between 10 and 100 ug/kg. There are 76 detected values (58 percent) between 1 and 10 ug/kg. An addional 29 samples, 22 percent of the detected data set, are detected at concentrations less than 1 ug/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the total DDx data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Total DDx were analyzed in ~~The results of the~~ 1,2~~1~~0~~4~~9 surface sediment samples and detected in 1,130 samples within the Study Area (detection frequency of 90 percent), with concentrations ranging from ~~that were analyzed for both the 2,4'- and 4,4'-isomers of the DDx compounds are depicted on Map 5.1-7. Detected concentrations ranged from an estimated~~ 0.051 NJ µg/kg to an estimated 84,900 A µg/kg ~~in surface sediment~~ (Table 5.2~~1~~-1~~; Figure 5.1-11~~). ~~Ninety-five percent of the samples were less than 470 JV µg/kg.~~ Total DDx concentrations in surface sediment varied along the Study Area (Figure 5.2-14 and Map 5.2-11). Total DDx concentrations greater than 100 ug/kg in the scatter plots (Figure 5.2-14) are indicated as yellow, orange, and red dots on Map 5.2-11.

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Areas of total DDx concentrations greater than 100 µg/kg occurred at several locations scattered along the nearshore zones and channel margins (Figure 5.2~~1~~-13~~4~~4~~1~~). Areas exceeding 100 ug/kg total DDx in the eastern nearshore zone include Swan Island Lagoon and RM 11-11.8. Map 5.2-11 shows that the RM 11 concentrations are clustered in a small area while the Swan Island Lagoon concentrations are more dispursed. The mean concentrations (see Table 5.2-3) for these areas in the eastern nearshore zone are: 16 ug/kg for Swan Island Lagoon and 42 ug/kg for RM 11 to 11.8.

Areas exceeding 100 ug/kg total DDx in the western nearshore zone extends from RM 3 through RM 9. The most prominent area of total DDx concentrations greater than 100 µg/kg occurred along the western shoreline between RM 6.3 and 7.5 where~~. C~~

concentrations above 10,000 µg/kg (shown in red on Map 5.2~~1~~-11~~7~~) were found ~~only in surface sediment~~ near the ~~western shore at~~ RM 7.2~~5~~. The maximum concentration was found at Station OSS002 in this vicinity. Another prominent peak is located ~~U~~upstream along the western shoreline at RM 8.8, where DDx was detected in a single sample at a concentration greater than 1,000 µg/kg. Mean concentrations (see Table 5.2-7) for these areas in the western nearshore zone are: 27 ug/kg for RM 3 to 4; 23 ug/kg for RM 4 to 5; 36 ug/kg for RM 5 to 6; 190 ug/kg for RM 6 to 7; 2,720 ug/kg for RM 7 to 8; and 123 ug/kg for RM 8 to 9.

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With the exception of four samples, ~~samples collected~~total DDx concentrations within the navigation channel were less than 100 µg/kg. Concentrations greater than 100 µg/kg (Figure 5.2-14) were located at RM 5.6 (maximum concentration of 148 ug/kg), RM 6.5 (maximum concentration of 274 J ug/kg), and RM 11.3 (~~Figure 5.1-11~~maximum concentration of 140 ug/kg), which are likely collocated with contamination in the nearshore zones in those river miles. The mean concentrations for these areas are: 13 ug/kg for RM 5 to 6; 29 ug/kg for RM 6 to 7; and 25 ug/kg for RM 11 to 11.8.

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~~The DDD, DDE, and DDT components show generally similar patterns of distribution, though relative concentrations vary (Maps D1.1-3, D1.1-5, and D1.1-7).~~Tables 5.2-9 and 5.2-10 show that there are 7 data points greater than 10,000 ug/kg. These are located in the western nearshoe zone between RM 7.2 and 7.5. There are 22 detected values between 1,000 and 10,000 ug/kg, which are primarily located within the same western nearshore zone with one sample being located at RM 8.8. An additional 92 samples, ~~eith~~eight percent of the detected data set, were detected at concentrations between 100 and 1,000 ug/kg. Surface sediment samples greater than 100 ug/kg accounts for 11 percent of the detected data set (Map 5.2-11). Another 327 samples, or 28 percent of the detected data set, is between 10 and 100 ug/kg. Over half the detected data set (636 samples; 56 percent) is comprised of concentrations ranging between 1 and 10 ug/kg and 46 samples (four percent) were detected at a concentration less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

Total DDx were analyzed in 25 surface sediment samples and detected in 22 samples within the Downstream reach (detection frequency of 88 percent), with concentrations ranging from 0.2 A ug/kg to 30 J ug/kg (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there are three samples greater than 10 ug/kg. The majority of the detected data set (14 samples; 64 percent) were detected at concentrations ranging between 1 and 10 ug/kg. Only five samples were detected at concentrations less than 1 ug/kg. The mean total DDx concentration in this reach is 5.2 ug/kg.

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~~5.13.11.2~~5.2.4.3 Total DDx in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

~~This draft document has been provided to EPA at EPA's request to facilitate EPA's comment process on the document in order for LWG to finalize the RI. The comments or changes (including redlines) on this document may not reflect LWG positions or the final resolution of the EPA comments.~~

Total DDx concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 1.0 ug/kg and 9.7 ug/kg; the average concentration for this reach is 5.8 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

Total DDx were analyzed in 94 subsurface sediment samples and detected in 64 samples within the Downtown reach (detection frequesncy of 68 percent), with concentrations ranging from 0.05 ug/kg to 301 ug/kg (Table 5.2-16a) and a mean concentration of 16 ug/kg. Tables 5.2-17 and 5.2-18 show that there is one value detected above 100 ug/kg. There are 19 detected values between 10 and 100 ug/kg. Half of the detected data set (32 samples) were deteted at concentrations between 1 and 10 ug/kg. The remaining data set (11 samples) were detected at concentrations less than 1 ug/kg. None of the subsurface samples were analyzed in the vicinity of the Zidell facility.

Study Area Reach (RM 1.9 to 11.8)

Of the 1,678~~291~~ subsurface samples analyzed for total DDx, 1,393 were detected (83 percent detection frequency) with concentrations ranging~~ed~~ from an estimated 0.058 J µg/kg to an estimated 3,643,000 A µg/kg ~~in subsurface sediment~~ (Table 5.2~~1~~-2) and a mean concentration of 11,200 ug/kg. Similar to surface sediment, total DDx concentrations in the subsurface also varied within the Study Area (Figure 5.2-14; Maps 5.2-12a-o and 5.2-13a-gg).

Areas of total DDx concentrations greater than 100 µg/kg occurred at several locations scattered along the nearshore zones and channel margins (Figure 5.2-14). Areas exceeding 100 ug/kg total DDx in the eastern nearshore zone include one point at RM 5-6; one point at RM 6-7; Swan Island Lagoon; and RM 11-11.8. Maps 5.2-12a-o and 5.2-13a-gg show that the RM 11 concentrations are clustered in a small area while the Swan Island Lagoon concentrations are more dispursed. The mean concentrations (see Table 5.2-4) for these areas in the eastern nearshore zone are: 56 ug/kg for RM 5 to 6; 103 ug/kg for RM 6 to 7; 65 ug/kg for Swan Island Lagoon; and 464 ug/kg for RM 11 to 11.8.

Like the surface sediment, areas exceeding 100 ug/kg total DDx in the western nearshore zone extends from RM 3 through RM 9. The most prominent area of total DDx concentrations greater than 100 µg/kg occurred along the western shoreline between RM 6.3 and 7.5 where concentrations above 10,000 µg/kg (shown in red on Map 5.2-11) were also found near the RM 7.2.

The maximum subsurface concentration was found in the interval 323 to 384 cm bml at Station WB-24 at RM 7.2E. -Another prominent peak is located upstream along the western shoreline at RM 8.8, where DDx was detected in a single sample at a concentration greater than 1,000 µg/kg. The area downstream of RM 7.2 to

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approximately RM 6.5 also exceeds 1,000 ug/kg. Mean concentrations (see Table 5.2-8) for these areas in the western nearshore zone are: 39 ug/kg for RM 3 to 4; 77 ug/kg for RM 4 to 5; 78 ug/kg for RM 5 to 6; 322 ug/kg for RM 6 to 7; 36,900 ug/kg for RM 7 to 8; and 153 ug/kg for RM 8 to 9.

Total DDx concentrations within the navigation channel exceed 100 µg/kg (Figure 5.2-14) were located from RM 3.2 to RM 5 and from RM 5.5 to RM 8.1, RM 10.9 to RM 11.5, which are correspond with contamination in the nearshore zones in those river miles. The mean concentrations for these areas are: 18 ug/kg for RM 3 to 4; 74 ug/kg for RM 4 to 5; 19 ug/kg for RM 5 to 6; 229 ug/kg for RM 6 to 7; and 67 ug/kg for RM 7 to 8; and 11 ug/kg for RM 11 to 11.8.

Tables 5.2-9 and 5.2-10 show that there are 51 data points greater than 10,000 ug/kg. These are located in the western nearshoe zone between RM 7.2 and 7.5. There are 83 detected values between 1,000 and 10,000 ug/kg, which are primarily located within the same western nearshore zone with one sample being located at RM 8.8. An additional 200 samples, 14 percent of the detected data set, were detected at concentrations between 100 and 1,000 ug/kg. Subsurface sediment samples greater than 100 ug/kg accounts for 24 percent of the detected data set. Another 489 samples, or 35 percent of the detected data set, is between 10 and 100 ug/kg. An additional one third the detected data set (425 samples; 31 percent) is comprised of concentrations ranging between 1 and 10 ug/kg and 145 samples (ten percent) were detected at a concentration less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

Total DDx were analyzed in 26 subsurface sediment samples and detected in 17 samples within the Downstream reach (detection frequency of 65 percent), with concentrations ranging from 0.28 NJ ug/kg to 80 NJ ug/kg (Table 5.2-20). Tables 5.2-21 an~~m~~d 5.2-22 show that there are 11 samples, 65 percent of the detected data set, are detected at concentrations between 10 and 100 ug/kg. Four samples were detected at concentrations between 1 and 10 ug/kg and two samples were detected at a concentration less than 1 ug/kg. The mean total DDx concentration in theis reach is 19 ug/kg.

~~Of the samples collected within the navigation channel, the cores with concentrations greater than 100 µg/kg corresponded to areas of similar concentrations within the nearshore (Figure 5.1-12; Maps 5.1-8a–m).~~

~~5.13.11.4~~5.2.4.4 Total DDx Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean total DDx surface sediment concentration in this reach is 2 ug/kg.

The surface sediment concentrations in the downtown reach were less than the subsurface concentration. The mean surface concentration is 6.6 ug/kg, while the mean subsurface sediment concentration is 16 ug/kg.

~~The magnitude of total DDx mean surface and subsurface sediment concentrations is shown on Figure 5.1-42. Summary statistics are presented in Table 5.1-5. The methods used to develop these presentations are described in Section 5.1.5.4.~~

~~With the exception of one area (RM 11-11.8), t~~The mean subsurface concentration~~s~~ of DDx ~~are~~ is generally higher than the surface concentrations throughout the Study Area (Figure 5.2~~1~~-16~~42~~). ~~The magnitude of the ratios are generally low, mostly around 5 or less; however, at~~ This figure also shows that the western shore of RM 7-8 is the most contaminated area; ~~W,~~ the mean subsurface levels in this area greatly exceed the surface mean.~~,~~ This indicat~~es~~ing a large historical source or sources that ha~~ve~~s been markedly reduced over time. The one area of exception is RM 8-9 on the eastern shore where the mean surface sediment concentration (16 ug/kg) is greater than the mean subsurface concentration (10 ug/kg), although slightly. ~~The only portions of the Study Area where surface sediment total DDx concentrations are higher than subsurface sediments are from RM 11–11.8E and in the navigation channel, possibly suggesting a current source or sources, but the magnitude of these ratios is relatively low. The surface/subsurface trends revealed by Figure 5.1-42 are supported by the data plotted in Maps 5.1-8a-m.~~Figure 5.2-14 shows that concentrations are generally greater in nearshore areas than in the navigation channel and the western nearshore zone is greater than the eastern nearshore zone.

Areas where subsurface sediment concentrations exceed 100 ug/kg generall align with the locations where surface sediment concentrations are greater than 100 ug/kg (Maps 5.2-11, 5.2-12a-o, and 5.2-13a-gg; Figures 5.2-13, 5.2-14 and 5.2-15). Exceptions occur in the eastern nearshore zone from RM 3 to 5 and RM 7 to 8, the navigation channel from RM 7 to 11, and the western nearshore area from RM 9 to 10 where subsurface concentrations exceed 100 ug/kg, but surface sediment concentrations do not.

The subsurface sediment concentrations in the downstream reach were greater than surface concentrations. The eman surface concentration is 5.2 ug/kg, while the mean subsurface concentration is 19 ug/kg.

5.2.4.5 Total DDx Sediment Relationships by River Reach

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Comparisons of the total PCB data sets between the river reaches (Upriver, Downtown, Study Area and Downstream) are discussed using the summary statistics tables and box-whisker plots.

Surface Sediment

There were far more data points in the Study Area reach (1,249) than in the other river reaches (Upriver – 81; Downtown – 149; Downstream – 25) which may affect the comparability of the data sets.

The Study Area reach has the highest median of 7.5 J ug/kg (Table 5.2-1), followed by the Downtown and Downstream reach medians of 3.1 J ug/kg (Tables 5.2-15a and 5.2-19) and the Upriver reach median of 1.7 J ug/kg (Table 5.2-11). These tables show the mean concentrations of the data sets generally follow the same pattern: Study Area reach (268 ug/kg); Downtown reach (6.6 ug/kg); Downstream reach (5.2 ug/kg); and Upriver reach (2 ug/kg).

A box-whisker plot showing the relationship of total DDx in sediment between the river reaches is presented in Figure 5.2-16. The box-whisker plots were plotted using bith detected and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the Upriver, Downtown and Downstream data sets are small compared to the Study Area data set. The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the medial with a long upper whisker representing a large dispersion of the relative data in the upper range of the data set.The Upriver and Downstream reaches exhibit upward skewness, while the Study Area exhibits downward skewness. The Downtown reach exhibits no skewness.

Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Upriver and Study Area data sets, followed by the Upriver and Downstream, Study Area and Downstream, Study Area and Downtown, Downtown and Downstream, and Upriver and Downtown. Whether or not these differences are statistically significant is partl a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of the Upriver reach, the Downtown reach and the Downstream reach overlap; thus, there is no difference between these data sets. The spread of the Upriver reach does not overlap the spread of the Study Area reach indicating that the Study area data set is greater than the Upriver data set. The spread of the Downtown and Downstream data sets overlap the spread of the Study area; however, the medians do not overlap the spreads. Consequently, it is likely that the majority of the data points for the Study Area are greater than the data points for the Downtown and Downstream data sets.

Subsurface Sediment

The Upriver subsurface data set is comprised of only three data points; thus there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like the surface sediment, the Study Area reach has far more data points (1,678) than the other reaches (Downtown – 94; Downstream – 26) which may have an effect on the comparison of the data sets.

The Study Area has the highest median of 15 J ug/kg (Table 5.2-2), followed by the Downstream reach median of 12 A ug/kg (Table 5.2-20) and the Downtown reach median of 5.7 A ug/kg (Table 5.2-16a). These tables also show the means of the data sets result in the same order of the reaches: Study Area reach (11,200 ug/kg), Downstream reach (19 ug/kg), and Downtown reach (16 ug/kg).

A box-whisker plot showing the relationship of total DDx in sediment between the river reaches is presented in Figure 5.2-16. The box-whisker plots were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set.

The relative dispersion of the Upstream data set is comparatively small due to the small number of data points (i.e., three). The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative data in the upper range of the data set. Like the surface sediment plots, the whiskers on the low end are indicative of the detection limits for the data set. However, the lower bound whisker on the Study Area and Downtown subsurface plots show that lower detection limits were used for these data set compared to the Downstream data set, which would tend to skew the data downward. This will result in the comparisons of other data sets to the Downstream data set being less reliable. The Upriver reach exhibits an upward skewness, while all the other reaches exhibit no noticable skewness. The Study Area data set is four orders of magnitude (ie., 10,000 times) greater than the the other data sets.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually overlap of the spread in all the data sets. The spread and medians of the Downstream reach, the Study Area reach, and the Downtown reach all overlap each other; hence there is no difference between these data sets. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

~~5.13.13.0 Patterns and Trends of Total DDx in Sediment~~

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~~DDx patterns appeared to vary widely across the Study Area, as shown in Figures 5.1-43a–h (surface sediments) and 5.1-44a–d (subsurface sediments). Selected potential trends are summarized below. The bar charts in these figures include samples that may lack results for the 2,4'-isomers of a DDx compound if these were not analyzed (see Appendix D1.6). The DDx patterns are incomplete for these samples. The discussion of subsurface sediment trends is based on the evaluation of DDx patterns only for the depth interval with the highest concentration at each location, presented in Figures 5.1-44a–d. The DDx composition at other depths may differ from that at the depth of maximum concentration.~~

~~As noted above, total DDx concentrations exceeded 10,000 µg/kg in one area located near RM 7 in the western nearshore zone. The main constituent of the surface sediments in this area was the 4,4'-isomer of DDT (Figure 5.1-43g), while the 4,4'-isomers of DDT and DDD were the main constituents of the subsurface sediments (Figure 5.1-44d). This pattern may indicate degradation of DDT to DDD in deep anoxic sediments.~~

~~The relative concentrations of the DDx isomers appear highly variable from station to station across the Study Area in both surface and subsurface sediment samples. However, a few general trends were observed:~~

- ~~The 4,4'-isomer concentrations were greater than those for the 2,4'-isomers of the DDx constituents overall. In some locations, the 2,4'-isomers were more abundant than their 4,4'- counterparts, particularly 2,4'-DDD and, less frequently, 2,4'-DDT. 2,4'-DDE was rarely detected and was dominant only in samples with relatively low concentrations.~~
- ~~Overall, samples with the highest concentrations tended to display a dominance of DDT and/or DDD isomers, particularly below RM 8.~~
- ~~There was a broad potential trend observed in the western nearshore DDx patterns. Both surface and subsurface sediment samples collected upstream of RM 8 generally had relatively low total DDx concentrations (typically between 10 and 100 µg/kg) and a large DDE component, whereas samples collected between RM 7.5 and 6.9 had relatively higher total DDx concentrations (generally higher than 100 µg/kg) and were dominated by DDT, and samples downstream of RM 6.9 had relatively lower total DDx concentrations (generally less than 100 µg/kg) and a larger apparent DDD component. These upstream/downstream trends were also evident in the navigation channel, which generally paralleled the western nearshore trends from RM 12 to about RM 4 (except where embayments such as Willbridge are crossed). In contrast, the eastern nearshore patterns were more like those of the western nearshore zone above RM 8.~~

~~5.13.20~~5.2.5 Total PAHs in Sediment

~~The distribution and composition of total PAH concentrations in Study Area sediment are summarized in this section.~~ Several data presentations for the surface and subsurface total PAHs data set within the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. The distribution of total PAHs concentrations at each surface sediment sampling station throughout the Study Area is depticted on Map 5.2-14; concentrations with depth at subsurface stations are depicted on Maps 5.2-15a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented. Detailed subsurface sediment chemistry in the Study Area is presented on Maps 5.2-16a-gg, including a key for interpreting the detailed subsurface chemistry maps.

Figures 5.2-17 and 5.2-18 present scatter plots of the total PAHs data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for total PAHs in the surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigational channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total PAHs data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detect and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-19.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-40. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-6; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-20.

5.2.5.1 Total PAHs Data Set

Total PAHs is the sum of the individual PAH compound concentrations. Frequencies of detection of PAH compounds were high, approximately 99 percent in surface samples and 95 percent in subsurface samples. The Study Area data set of total PAH concentrations includes 1,661~~03~~ surface samples and 1,696~~545~~ subsurface samples. The Upriver data set includes 78 surface samples and 3 subsurface samples. The downtown data set includes 269 surface samples and 161 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples.~~Frequencies of detection of PAH compounds were high, approximately 99 percent in surface samples and 95 percent in subsurface samples.~~

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~~Map 5.1-9 shows the distribution of total PAH concentrations at each surface sampling station throughout the Study Area; concentrations with depth at subsurface stations are depicted in Maps 5.1-10a–m. The complete data set is plotted on scatter plots presented in Figures 5.1-13 and 5.1-14.~~

~~5.13.20.2~~5.2.5.2 Total PAHs in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

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Total PAHs were analyzed in 78 surface sediment samples and detected in 63 samples within the Upriver reach (detection frequency of 81 percent), with detected concentrations ranging from 0.91 J ug/kg to 1,510 ug/kg (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that there is only one data point greater than 1,000 ug/kg. There are 17 data points (27 percent of the detected data set) ranging from 100 to 1,000 ug/kg. The majority of the data set (39 samples; 62 percent of the detected data set) is comprised of concentration ranging from 10 to 100 ug/kg. Another 5 samples, or eight percent of the detected data set, was detected at concentrations ranging from 1 to 10 ug/kg and only one data point was detected at a concentration less than 1 ug/kg. The mean total PAHs concentration in this reach is 74 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

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Total PAHs were analyzed in 269 surface sediment samples and detected in 248 samples within the Downtown reach (detection frequency of 92 percent), with detected concentrations ranging from 0.73 to 62,500 ug/kg (Table 5.2-15a) and a mean concentration of 2,174 ug/kg. Total PAHs concentrations in surface sediment varied along the Downtown reach (Map 5.2-40). The map shows that the majority of the samples exceeding 10,000 are between RM 13.5 and 14 on the western bank; however, there some of the samples with the greatest concentration are located at RM 12.2 west, 12.3 east, and 12.5 west.

Tables 5.2-17 and 5.2-18 show that there are 11 data points greater than 10,000 ug/kg. There are 55 detected values between 1,000 and 10,000 ug/kg. Surface sediment values greater than 1,000 ug/kg accounts for 27 percent of the detected data set. Almost half of the surface sediment samples in this reach (49 percent) have concentrations ranging from 100 to 1,000 ug/kg. An additional 41 samples, 17 percent of the detected data set, were detected at concentrations between 10 and 100 ug/kg. Another 17 samples, or seven percent of the detected data set, are between 1 and 10 ug/kg and only three samples were detected at concentrations less than 1 ug/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Total PAHs were analyzed in 112 surface sediment samples (detection frequency of 88 percent), with concentrations ranging from 0.0734 ug/kg to 32,000 A ug/kg. The mean total PAHs concentration for this area is 2,538 ug/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15b), the range of total PAHs concentrations in surface sediment is from 0.57 J ug/kg to 62,500 ug/kg with a mean concentration of 1,940 ug/kg.

Study Area Reach (RM 1.9 to 11.8)

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Total PAHs were detected in 1,640 surface sediment samples within the Study Area (detection frequency of 99 percent). The concentration range of total PAHs in surface sediment varied widely, from 3.3 J µg/kg to 7,260,000 µg/kg (Table 5.2~~1~~-1). ~~Ninety-five percent of the 1,603 surface samples were less than 66,600 JV µg/kg.~~

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The data, particularly above RM 6.5 where samples are more abundant, showed variable concentrations throughout the Study Area (Figure 5.2-1).

Several locations within the Study Area have ~~Except for several areas of relatively higher concentrations, t~~total PAH levels ~~were generally~~ less than 1,000 µg/kg ~~or less in channel and nearshore zones of the main stem of the river (i.e., outside Swan Island Lagoon)~~. The lower end of the Study Area from RM 1.9 to 3 (except 2 samples in the eastern nearshore zone) has concentrations less than 1,000 ug/kg. The upper end of the Study Area from RM 10 to 11.8 (except 3 samples in the eastern nearshore zone) also has concentrations less than 1,000 ug/kg. Additionally, the eastern nearshore zone between RM 6 and 10 (except 3 samples) has concentrations less than 1,000 ug/kg. The only area in the Navigation Channel that exceeded 1,000 ug/kg is from RM 5 to 7~~in the upper portion of the Study Area between RM 7 and 11.8~~ (Figure 5.2~~1~~-1~~3~~7; Map 5.2~~1~~-14~~9~~).

Scattered areas of concentrations greater than 1,000 µg/kg were found throughout the Study Area, but the highest concentrations (>2~~3~~0,000 µg/kg; indicated in red and pink on Map 5.2~~1~~-14~~9~~) were most commonly found from RM 4.2 to 4.8 in the eastern nearshore zone and RM 5.9 to 6.8 in the western nearshore zone~~s~~ ~~between approximately RM 4 and 7.5~~ (Figure 5.2~~1~~-17; Map 5.2-14~~3~~). The highest surface sediment concentration (7,260,000 ug/kg) in the data set was detected at RM 6.3 in the western nearshore zone (Station G225).

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Total PAH concentrations above 2~~3~~0,000 µg/kg were also found in surface sediment in the navigation channel from RM 5.2 to 6.8 adjacent to the western nearshore zone ~~RM 5.2–6.8 reach~~.

The mean concentrations for areas in the eastern nearshore zone (Table 5.2-3) with concentrations exceeding 1,000 ug/kg are: 5,160 ug/kg for RM 1.9 to 3; 3,850 ug/kg for RM 3 to 4; 35,100 ug/kg for RM 4 to 5; 5,170 ug/kg for RM 5 to 6; 3,870 ug/kg for RM 6 to 7; 1,420 ug/kg for RM 7 to 8; 3,580 ug/kg for Swan Island Lagoon; 4,850 ug/kg for RM 10 to 11; and 3,640 ug/kg for RM 11 to 11.8.

The mean concentrations for the areas in the western nearshore zone (Table 5.2-7) with concentrations exceeding 1,000 ug/kg are: 4,740 ug/kg for RM 3 to 4; 7,940 ug/kg for RM 4 to 5; 17,300 ug/kg for RM 5 to 6; 192,000 ug/kg for RM 6 to 7; 3,490 ug/kg for RM 7 to 8; 2,280 ug/kg for RM 8 to 9; and 2,510 ug/kg for RM 9 to 10.

The mean concentrations for the areas in the navigation channel (Table 5.2-5) with concentrations exceeding 1,000 ug/kg are: 275,000 ug/kg for RM 5 to 6; and 58,600 ug/kg for RM 6 to 7.

Tables 5.2-9 and 5.2-10 show that there are 233 data points greater than 10,000 ug/kg. These are primarily located from RM 4.2 to 4.8 in the eastern nearshore zone and RM 5.9 to 6.8 in the western nearshore zone. There are 636 detected values between 1,000 and 10,000 ug/kg. Over half the data set (55 percent of the detected data) for the Study Area is found at concentrations greater than 1,000 ug/kg (Map 5.2-14). An additional 661 samples, 40 percent of the detected data set, were detected at concentrations between 100 and 1,000 ug/kg. Another 104 samples, or six percent of the detected data set, is between 10 and 100 ug/kg and six samples were detected at concentrations ranging from 1 to 10 ug/kg. There were no samples detected at concentrations less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

Total PAHs were analyzed and detected in 25 surface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 1.4 J ug/kg to 18,000 J ug/kg (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there is one sample greater than 10,000 ug/kg and one sample between 1,000 and 10,000 ug/kg. The majority of the detected data set (16 samples; 64 percent) were detected at concentrations ranging between 100 and 1,000 ug/kg. Another six samples were detected at concentrations between 10 and 100 ug/kg and only one sample detected between 1 and 10 ug/kg. There were no samples detected at concentrations less than 1 ug/kg. The mean total PAHs concentration in this reach is 1,120 ug/kg.

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~~5.13.20.3~~5.2.5.3 Total PAHs in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

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Total PAHs concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 253 ug/kg and 533 ug/kg; the average concentration for this reach is 366 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

Total PAHs were analyzed in 161 subsurface sediment samples and detected in 157 samples within the Downtown reach (detection frequesncy of 98 percent), with concentrations ranging from 0.25 J ug/kg to 4,850,000 ug/kg (Table 5.2-16a) and a mean concentration of 235,000 ug/kg. Tables 5.2-17 and 5.2-18 show that there are 30 samples greater than 10,000 ug/kg. Another 39 samples were detected at concentrations ranging between 1,000 and 10,000 ug/kg. Samples greater than 1,000 ug/kg accounts for 44 percent of the detected data set in this reach. One third of the data set (52 samples; 33 percent of the detected data set) is detected between 100 and 1,000 ug/kg. Additionally, there are 23 detected values, or 15 percent of the detected data set, ranging between 10 and 100 ug/kg. Only 6 samples (4 percent of the detected data set) were deteted at concentrations between 1 and 10 ug/kg. The remaining data set (7 samples) were detected at concentrations less than 1 ug/kg. Figure 5.2-18 shows that there is a significant peak in the western nearshore area at RM 12.2.

Twelve of the subsurface samples were analyzed in the vicinity of the Zidell facility. The concentrations ranged from 4.8 ug/kg to 451 ug/kg. The result of removing these low level concentrations from the Downtown data set is an increase in the mean and median concentrations; the mean concentration for the Downtown data set excluding the Zidell data is 235,000 ug/kg and the median is 770 ug/kg.

Study Area Reach (RM 1.9 to 11.8)

Total PAHs were analyzed in 1,715 subsurface samples and detected in 1,643 samples (detection frequency of 96 percent), with concentrations ranging from 0.15 J ug/kg to 53,300,000 ug/kg (Table 5.2-2). Similar to surface sediment, total PAH concentrations in the subsurface also varied within the Study Area (Figure 5.2-18; Maps 5.2-15a-o and 5.2-16a-gg).

~~Of the 1,545 subsurface samples analyzed for total PAHs, the concentration range varied widely, from 0.15 J µg/kg to 53,300,000 µg/kg in subsurface sediment (Table 5.1-2).~~

Similar to surface sediment, scattered areas of total PAH concentrations greater than 1,000 µg/kg in subsurface sediment were found throughout the Study Area.~~, and~~ C~~c~~oncentrations greater than 1~~3~~0,000 µg/kg were most commonly found in the eastern nearshore zone between RM 3.5 and 7.5 and in Swan Island Lagoon. Mean subsurface sediment concentrations in the eastern nearshore zone (Table 5.2-4) for each river mile in these areas are: 22,000 ug/kg for RM 3 to 4; 23,500 ug/kg for RM 4 to 5; 11,600 ug/kg for RM 5 ro 6; 6,560 ug/kg for RM 6 to 7; 3,010 ug/kg for RM 7 to 8; and 3,400 for Swan Island Lagoon.

Concentrations of total PAHs greater than 10,000 ug/kg were also found in the~~and~~ western nearshore zone~~s~~ between approximately RM 3 and 7.5 and at RM 9.2 (Figure 5.2~~1~~-18~~4~~; Maps 5.2~~1~~-15~~0~~a–0 and 5.2-16a-gg~~m~~). The most prominent peak of total PAH concentrations is found between RM 6 and 6.5. The highest subsurface concentration (53,300,000 ug/kg) is also found in this area (Station C302). Mean subsurface sediment concentrations in the western nearshore zone (Table 5.2-8) for each river mile in these areas are: 19,000 ug/kg for RM 3 to 4; 24,700 ug/kg for RM 4 to 5; 45,400 ug/kg for RM 5 to 6; 1,610,000 ug/kg for RM 6 to 7; 3,560 ug/kg for RM 7 to 8; and 19,200 ug/kg for RM 9 to 10.

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PAH concentrations above ~~3~~10,000 µg/kg were also found in subsurface sediment in the navigation channel from RM 4 to 6.5, adjacent to and downstream from the high concentration area in the western nearshore zone between RM 6 and 6.5. Mean concentration (Table 5.2-6) for each river mile in the navigation channel with concentrations exceeding 10,000 ug/kg are: 5,240 ug/kg for RM 4 to 5; 8,450 ug/kg for RM 5 to 6; and 453,000 ug/kg for RM 6 to 7.

Tables 5.2-9 and 5.2-10 show that there are 335 data points greater than 10,000 ug/kg. There are an additional 563 detected values between 1,000 and 10,000 ug/kg. Subsurface sediment values greater than 1,000 ug/kg accounts for over half (54 percent) of the detected data set. Another 484 samples, 29 percent of the detected data set, were detected at concentrations between 100 and 1,000 ug/kg. Only 137 samples, eight percent of the detected data set, were detected at concentrations between 10 and 100 ug/kg. Merely 87 samples, five percent of the detected data set, were detected at concentration between 1 and 10 ug/kg and 37 samples, two percent of the detected data set, were detected at concentrations less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

Total PAHs were analyzed and detected in 26 subsurface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 0.49 J ug/kg to 23,000 ug/kg (Table 5.2-20). Tables 5.2-21 and 5.2-22 show that there is one sample greater than 10,000 ug/kg and four samples were detected at concentrations between 1,000 and 10,000 ug/kg. Subsurface sediment values greater than 1,000 ug/kg accounts for 19 percent of the detected data set. There are 10 samples, 38 percent of the detected data set, are between 100 and 1,000 ug/kg. Another 7 samples, 27 percent of the detected data set, are detected at concentrations between 10 and 100 ug/kg. Two samples were detected at concentrations between 1 and 10 ug/kg and an additional two samples were detected at a concentration less than 1 ug/kg. The mean total PAH concentration in this reach is 1,340 ug/kg.

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~~5.13.20.4~~5.2.5.4 Total PAHs Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach.

There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean total PAH concentration in this reach is 107 ug/kg.

The surface sediment in the Downtown reach is substantially greater in the subsurface sediment than in the surface sediment. The mean surface sediment sediment concentration is 2,174 ug/kg, while the mean subsurface sediment concentration is 219,700 ug/kg.

Total PAH concentrations are generally greater in subsurface sediments than in surface sediments within the Study Area as a whole. The mean surface sediment concentration in the Study Area is 27,200 ug/kg and the mean subsurface sediment concentration is 249,000 ug/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-19 and Tables 5.2-3 through 5.2-8 show that mean concentrations are greater in the nearshore areas than in the navigation channel with the exception of RM 5 to 6, where the navigation channel has greater concentrations than the nearshore areas, and RM 6 to 7, where the naviagion channel has greater concentrations than the eastern nearshore area but less than the western nearshore area. The western nearshore zone generally has greater total PAH concentrations than the eastern nearshore zone between RM 5 and 10 while the eastern nearshore area has greater concentrations from RM 1.9 to 3, RM 4 to 5, in Swan Island Lagoon, and RM 10 to 11.8. The eastern and western nearshore areas have about the same concentrations from RM 3 to 4.

In the eastern nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles zones except from RM 1.9 to 3, RM 4 to 5, Swan Island Lagoon, RM 10 to 11, and RM 11 to 11.8. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles except RM 8 to 9. The subsurface sediment concentrations in the naviagion channel are generally greater than the surface sediment concentrations except from RM 5 to 6, RM 8 to 9, and RM 9 to 10.~~The magnitude of mean total PAH surface/subsurface sediment concentrations is shown on Figure 5.1-45. Summary statistics are presented in Table 5.1-6. The methods used to develop these presentations are described in Section 5.1.5.4.~~

~~The surface/subsurface mean ratios show that total PAH concentrations were slightly higher in subsurface sediments within the Study Area as a whole (left side of Figure 5.1-45).~~

Areas where total PAH concentrations are elevated in surface and subsurface sediment generally align (Maps 5.2-15a-o and 5.2-16a-gg and Figures 5.2-17, 5.2-18, and 5.2-19).

The total PAH concentrations for subsurface sediment in the downstream reach were greater than surface concentration. The mean surface sediment concentration is 1,120 ug/kg, while the mean subsurface concentration is 1,340 ug/kg.

5.2.5.5 Total PAH Sediment Relationships by River Reach

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Comparisons of the total PAH data sets between the river reaches (Upriver, Downtown, Downtown excluding Zidell, Study Area, and Downstream) are discussed using the summary statistics tables and box-whisker plots.

Surface Sediment

There were far more data points in the Study Area reach (1,661) than in the other river reaches (Upriver – 78; Downtown – 269; Downtown excluding Zidell – 157; and Downstream – 25) which may affect the comparability of the data sets.

The Study Area reach has the highest median of 1,180 ug/kg (Tabe 5.2-1), followed by the Downtown reach median of 338 J ug/kg (Table 5.2-15a), the Downtown reach excluding Zidell median of 259 J ug/kg (Table 5.2-15b), the Downstream reach median of 273 ug/kg (Table 5.2-19), and the Upriver reach median of 74 ug/kg (Table 5.2-11). These tables also show the means of the data sets result in the same order of reaches: Study Area reach (27,200 ug/kg), Downtown reach (2,174 ug/kg), Downtown excluding Zidell (1,940 ug/kg), Downstream reach (1,120 ug/kg), and Upriver reach (107 ug/kg).

A box-whisker plot showing the relationship of total PAHs in sediment between the river reaches is presented in Figure 5.2-20. The box-whisker plots were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set; the Downtown reach had the lowest detection limits. The relative dispersion of the Upriver and Downstream data sets is comparatively small. The length of the inner quartile for all reaches is small compared to the whiskers, suggesting a middle clustering of data about the median. The long upper whisker of the Study Area reach represents a large dispersion of the relative data in the upper range of the data set. All the data sets, except the Study Area, exhibit upward skewness.

Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Upriver and Study Area data sets, followed by the Upriver and Downstream, Study Area and Downstream, Upriver and Downtown, Upriver and Downtown excluding Zidell, Downtown and Study Area, Downtown excluding Zidell and Study Area, Downtown excluding Zidell and Downstream, and Downtown and Downstream. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) of the Upriver reach overlaps the spread of the Downtown excluding Zidell and Downtown reaches; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data points for the

Downtown reach are greater than the data points collected Upriver. This is also appearant with the Study Area reach with the Downtown reach, Downtown excluding Zidell, and the Downstream reach. There is no overlap of the Upriver reach with both the Study Area reach and the Downstream reach; hence, there is no difference between these two data sets. The spread and medians of the Downtown reach, Downtown reach excluding Zidell, and the Downstream reach all overlap each other; hence there is no difference between these data sets.

Subsurface Sediment

The Upriver subsurface data seet is comprised of only three nondetected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like the surface sediment, the Study Area reach has far more data points (1,715) than the other reaches (Downtown – 161; Downtown excluding Zidell – 149; Downstream – 26) which may have an effect on the comparison of the data sets.

The Study Area reach has the highest median of 1,390 ug/kg (Tabe 5.2-2), followed by the Downtown reach excluding Zidell median of 770 ug/kg (Table 5.2-16b), the Downtown reach median of 680 ug/kg (Table 5.2-16a), and the Downstream reach median of 310 J ug/kg (Table 5.2-20). These tables also show the means of the data sets result in the same order of the reaches: Study Area reach (249,000 ug/kg), Downtown reach excluding Zidell (235,000 ug/kg), Downtown reach (219,000 ug/kg), and Downstream reach (1,340 ug/kg). The reason that the Downtown reach excluding Zidell mean and median are greater than the Downtown reach with these data is that the data in the Downtown reach outside the area of the Zidell remedial action has concentrations greater than the levels within the Zidell remedial area.

A box-whisker plot (Figure 5.2-20) showing the relationship of total PAHs in sediment between the river reaches were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the Downstream data set is comparatively small. The length of the inner quartile for the Downtown, Downtown excluding Zidell, and Study Area reaches is small compared to the whiskers, suggesting a middle clustering of data about the median. The long upper whisker of the Study Area, Downtown, and Downtown excluding Zidell reaches represents a large dispersion of the relative data in the upper range of the data set. The Downstream data set exhibits upward skewness while both Downtown data sets exhibit downward skewness.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downstream and the other data sets, followed by the Downtown and Study Area data sets. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of all the reaches, excluding the Upriver reach, all overlap each other; hence there is no difference between these data sets.~~In areas where mean subsurface total PAH concentrations were greater than mean surface total PAH concentrations, the highest magnitude was at RM 6-7 in the navigation channel followed by RM 11–11.8 E. In areas where mean surface sediment total PAH concentrations were greater than subsurface concentrations the highest magnitude was at RM 5–6 in the navigation channel. Inspection of Map 5.1-10g indicates that the high subsurface mean at RM 6–7W is driven by some high PAH concentrations (>30,000 µg/kg) in core samples collected at the channel edge off of the Gasco early action area. The relatively high surface/subsurface mean ratio in the channel from RM 5–6 is driven by several high concentration (>30,000 µg/kg) surface-only samples in the channel.~~

~~5.13.20.5 Patterns and Trends of Total PAHs in Sediment~~

~~The distribution of detected PAHs at each location is presented in Figures 5.1-46a–j (surface sediment) and Figures 5.1-47a–f (subsurface sediment). In order to simplify the bar charts, PAHs were grouped according to the number of fused aromatic rings in the PAH. A list of individual PAHs included in the sum for each of these groups is provided in Table 5.1-7. Only PAHs analyzed for LWG samples are summed. Of these PAHs, two-ring PAHs include only naphthalenes (i.e., naphthalene and 2-methylnaphthalene). LPAHs include PAHs with two or three rings (green and yellow segments), and HPAHs include PAHs with four to six rings (purple, red, and blue segments). Only the depth interval that contained the highest total PAH concentration is shown in Figures 5.1-47a–f (i.e., the subsurface charts represent a variety of depths based on the interval of the maximum concentration) and evaluated below.~~

~~Surface sediments within the Study Area are generally dominated by HPAHs, primarily four-ring PAHs, with localized exceptions. Five-ring PAHs are the second most abundant HPAH, followed by six-ring PAHs. Three-ring PAHs are the principal LPAH in surface sediments, with two-ring PAHs generally being a minor component of the surface sediment PAH profile. Surface sediments from the western nearshore zone appeared to exhibit higher proportions of LPAHs than sediments from the eastern nearshore zone and the navigation channel, but follow the general trend of HPAH dominance. Some areas of high total PAH concentration have PAH profiles that appear to differ from the prevailing trend of HPAH dominance, the most notable between RM 6.2 and 6.9 in the western nearshore zone. In this area increased contributions from two and three-ring PAHs, and a corresponding reduced six-ring PAH abundance is also observed. Similar high PAH profiles are observed between RM 6.4 and 7.2 in the eastern nearshore zone and between RM 5.6 and 7.4 in the navigation channel.~~

~~Subsurface sediments appear to have greater contributions from two- and three-ring PAHs than the surface sediments, but generally exhibit similar PAH profiles to the surface sediments.~~

~~The proportions of individual PAH compounds varied throughout the Study Area, reflecting PAH contributions from multiple types of hydrocarbon sources, as well as~~

~~weathering and degradation. Hydrocarbon source types include pyrogenic (e.g., tars and creosote), petrogenic (e.g., fresh oil), and a variety of combustion processes and natural biological production processes. PAHs characteristic of these source types include alkylated PAH compounds, which are especially useful in distinguishing between pyrogenic and petrogenic source types. Alkylated PAH data are available for selected sediment and clam tissue samples and are presented in the SCRA database and summary statistics in Appendix D; however, these data are not discussed in the RI report. Once again, detailed forensic analyses would be required to identify significant differences among the PAH patterns within the sediment data set and to distinguish contributions from potential source types.~~

~~5.13.20 Additional Indicator Chemicals in Sediment~~

~~This section discusses the occurrence and distribution of nine additional ICs in sediment within the Study Area. The narrative in this section is less comprehensive than the preceding sections, omitting the data set description, surface/subsurface relationships, patterns and trends, and referring instead to maps, tables, and figures to provide a general picture of the distribution of those chemicals. The nature and extent data for the remaining 21 sediment ICs listed in Table 5.0-2 are presented on all tables, maps, and figures in Appendix D.~~

~~5.13.20.8~~5.2.6 Bis(2-ethylhexyl)phthalate in Sediment

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Several data presentations for the surface and subsurface bis(2-ethylheyl)phthalate (BEHP) data set withi the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. The distribution of BEHP concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-17; concentrations with depth at subsurface stations are depicted on Maps 5.2-18a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-21 and 5.2-22 present scatter plots of the BEHP data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for BEHP in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respecteively. Tables 5.2-9 and 5.2-10 present BEHP data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-23.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-41. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-2-; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-24.

5.2.6.1 BEHP Data Set

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The Study Area data set of BEHP concentrations includes 1,513 surface samples and 1,591 subsurface samples. The Upriver data set includes 72 surface samples and 3 subsurface samples. The downtown data set includes 96 surface samples and 64 subsurface samples. The downstream data set includes 21 surface samples and 17 subsurface samples. There are several nondetect values that exceed detected values (Figures 5.2-21 and 5.2-22); thus, the majority of this discussion will focus on the detected values only since meaningful conclusions cannot be drawn from the elevated nondeted values.

5.2.6.2 BEHP in Surface Sediment

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Upriver Reach (RM 15.3 to 28.4)

BEHP was analyzed in 72 surface sediment samples and detected in 56 samples within the Upriver reach (detection frequency of 78 percent), with detected concentrations ranging from 4.2 J ug/kg to 2,100 ug/kg (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that there is one data point greater than 1,000 ug/kg. Another 9 samples, 16 percent of the detected data set, was detected at concentrations ranging from 100 to 1,000 ug/kg. The majority of the detected data set (71 percent; 40 samples) is comprised of concentrations ranging between 10 and 100 ug/kg. An addtional six samples, or 11 percent of the detected data set, was detected at a concentration between 1 and 10 ug/kg. The mean BEHP concentration in this reach is 94 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

BEHP was analyzed in 96 surface sediment samples and detected in 78 samples within the Downtown reach (detection frequency of 81 percent), with detected concentrations ranging from 7.6 J ug/kg to 18,000 ug/kg (Table 5.2-15a) and a mean concentration of 418 ug/kg. The BEHP concentrations in surface sediment varied along the Downtown reach (Map 5.2-41). The map shows that the majority of the samples are less than 745 ug/kg in this reach and that there is no discernable pattern to the surface sediment samples greater than this value.

Tables 5.2-17 and 5.2-18 show that there is one sample greater than 10,000 ug/kg and one sample between 1,000 and 10,000 ug/kg. The majority of the data, 91 percent of the detected data set, is in the range of 10 to 1,000 ug/kg; 32 data points range between 100 and 1,000 and 39 data points range between 10 and 100 ug/kg. There are only 5 detected values (6 percent) between 1 and 10 ug/kg and no samples detected at concentrations less than 1 ug/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the BEHP data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

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BEHP was analyzed in 1,513 surface sediment samples and detected in 932 samples within the Study Area (detection frequency of 62 percent) with concentrations ranging from 7 J ug/kg to 440,000 ug/kg (Table 5.2-1). The mean BEHP concentration of surface sediment in the Study Area is 1,050 ug/kg. BEHP concentrations in surface sediment varied along the Study Area (Figure 5.2-21).

Two prominent peaks (>1,000 ug/kg) in the surface sediment are identified in the eastern nearshore zone (Figure 5.2-21). ~~Concentrations of BEHP were ≤1,500 µg/kg in the majority of samples analyzed (Maps 5.1-11 and 5.1-12a–m, see frequency plot inset; Figures 5.1-15 and 5.1-16). Limited areas with concentrations greater than 1,500 µg/kg were found at several locations within the Study Area. Frequencies of detection were 61 percent for surface samples and 39 percent for subsurface samples. Ninety-five percent of the surface samples were below 2,230 JV µg/kg (Table 5.1-1).~~

Clusters of concentrations greater than 1,0~~5~~00 µg/kg occur~~red in the surface data set from the eastern nearshore,~~ in Swan Island Lagoon~~,~~ and between RM 3.8 and 4.1 in the International Terminals Slip and along the riverfront (Maps 5.2~~1~~-17~~1 and 5.1-12a–m~~). The highest surface concentration detected in the Study Area was found at Station G367 at the mouth of Swan Island Lagoon. Additional samples greater than 1,000 ug/kg are located between RM 7 and 8 and at RM 11.2. Mean BEHP concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 1,310 ug/kg for RM 3 to 4; 792 ug/kg for RM 4 to 5; 573 ug/kg for RM 7 to 8; 6,150 ug/kg in Swan Island Lagoon; and 204 ug/kg for RM 11 to 11.8.

The western nearshore zone has detected BEHP concentrations that exceed 1,000 ug/kg from RM 6 through 10. It appears that there may be a prominent peak at RM 8.8 (Figure 5.2-21), but the remainder of the elevated concentrations appear to be more dispersed. Mean concentrations (Table 5.2-7) for this area in the western nearshore zone are: 256 ug/kg for RM 6 to 7; 347 for RM 7 to 8; 745 ug/kg for RM 8 to 9; and 531 ug/kg for RM 9 to 10.

The only prominent peak in the navigation channel zone is located around RM 10, which is mostly associated with eastern nearshore area (Map 5.2-17). Additional elevated samples are located at RM 5.2, Swan Island Lagoon, and RM 10.3 in the western nearshore area (Map 5.2-17. The mean concentrations for these areas are: 203 ug/kg for RM 5 to 6; 679 ug/kg for Swan Island Lagoon; and 446 ug/kg for RM 10 to 11 (Table 5.2-5).

Table 5.2-9 shows that there are nine detected data points in surface sediment greater than 10,000 ug/kg and there are 79 detected values between 1,000 and 10,000 ug/kg. Surface sediment values greater than 1,000 ug/kg accounts for nine percent of the detected data set. Over half the data set (501 samples; 54 percent of the detected data set) were detected at concentrations between 100 and 1,000 ug/kg. Another 336 samples, 36 percent of the detected data set, were detected at concentrations ranging from 10 to 100 ug/kg. There were seven samples, one percent of the detected data set, detected at concentrations between 1 and 10 ug/kg and no samples detected at concentrations less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

BEHP was analyzed in 21 surface sediment samples and detected in 10 samples within the Downstream reach (detection frequency of 48 percent), with concentrations ranging from 7.1 J ug/kg to 170 ug/kg (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there are two samples greater than 100 ug/kg. The majority of the detected data set (7 samples; 70 percent) were detected at concentrations ranging between 10 and 100 ug/kg. Only one samples was detected at concentrations less than 10 ug/kg. The mean BEHP concentration in this reach is 64 ug/kg.

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5.2.6.3 BEHP in Subsurface Sediment

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Upriver Reach (RM 15.3 to 26)

BEHP concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 20 J ug/kg and 3,800 ug/kg; the average concentration for this reach is 1,300 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

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BEHP was analyzed in 64 subsurface sediment samples and detected in 36 samples within the Downtown reach (detection frequesncy of 56 percent), with concentrations ranging from 2.5 J ug/kg to 815 ug/kg (Table 5.2-16a) and a mean concentration of 103 ug/kg. Table 5.2-17 shows that there are eight values detected above 100 ug/kg. Over half of the detected data set (23 samples; 64 percent) were deteted at concentrations between 1 and 10 ug/kg. The remaining data set (five samples) were detected at concentrations less than 10 ug/kg. None of the subsurface samples were analyzed in the vicinity of the Zidell facility.

Study Area Reach (RM 1.9 to 11.8)

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Of the 1,591 subsurface samples analyzed for BEHP, 635 were detected (40 percent detection frequency) with concentrations ranging from an estimated 2.4 J µg/kg to 18,000 µg/kg (Table 5.2-2) and a mean concentration of 345 ug/kg. Similar to surface sediment, BEHP concentrations in the subsurface also varied within the Study Area (Figure 5.2-22; Maps 5.2-18a-o).

Two prominent peaks (>1,000 ug/kg) in the subsurface sediment are identified in the eastern nearshore zone (Figure 5.2-21). Clusters of concentrations greater than 1,000 µg/kg occur in Swan Island Lagoon and between RM 3.6 and 4.4 in the International Terminals Slip and along the riverfront (Map 5.2-18). Mean BEHP concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 586 ug/kg for RM 3 to 4; 23,500 ug/kg for RM 4 to 5; and 650 ug/kg in Swan Island Lagoon.

The western nearshore zone has detected BEHP concentrations that exceed 1,000 ug/kg from RM 6 through 10. It appears that there are several prominent peaks close together or more diffuse distribution (Figure 5.2-21 and Maps 5.2-18g,h,j,k). ~~The highest surface concentration detected in the Study Area was found at Station G367 at the mouth of Swan Island Lagoon.~~

~~Additional isolated occurrences of concentrations greater than 1,500 µg/kg were found. With few exceptions, these concentrations occurred outside the navigation channel, in the eastern and western nearshore zones.~~ The ~~most notable exception is the western side of the navigation channel at RM 10.3, where the~~ highest subsurface concentration (18,000 ug/kg) in the Study Area was found in the interval of 0–195 cm bml at Station WR-VC-110 (RM 10.3). ~~A similarly elevated subsurface concentration was detected in the channel at RM 8 near the mouth of Swan Island Lagoon.~~Mean concentrations (Table 5.2-6) for this area in the western nearshore zone are: 338 ug/kg for RM 6 to 7; 277 for RM 7 to 8; 628 ug/kg for RM 8 to 9; and 359 ug/kg for RM 9 to 10.

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The only prominent peak in the navigation channel zone is at RM 7.9, which is most likely associated with Swan Islan Lagoon (Map 5.2-18i). An additional elevated sample is located at RM 10.3, which is located near the western nearshore area (see Map 5.2-18l). The mean concentrations for these areas are: 910 ug/kg for RM 7 to 8; and 502 ug/kg for RM 10 to 11 (Table 5.2-6).

Table 5.2-9 shows that there are two data points greater than 10,000 ug/kg. These are located in the navigation channel zone at RM 7.9 and 10.3. There are 32 detected values between 1,000 and 10,000 ug/kg, which are primarily located within the peak areas discussed above. Subsurface sediment samples greater than 1,000 ug/kg accounts for five percent of the detected data set. An additional 257 samples, 40 percent of the detected data set, were detected at concentrations between 100 and 1,000 ug/kg. Half of the detected data set (317 samples) is between 10 and 100 ug/kg. An additional 27 samples (four percent) is comprised of concentrations ranging between 1 and 10 ug/kg and there were no samples detected at a concentration less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

BEHP was analyzed in 17 subsurface sediment samples and detected in 16 samples within the Downstream reach (detection frequency of 94 percent), with concentrations ranging from 3.1 J ug/kg to 39 ug/kg (Table 5.2-20). Tables 5.2-21 and 5.2-22 show that there are five samples detected at concentrations greater than 10 ug/kg and eleven samples detected at concentrations less than 10 ug/kg. The mean BEHP concentration in this reach is 8.2 J ug/kg.

5.2.6.4 BEHP Surface and Subsurface Sediment Relationships

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Surface and subsurface sediment relationships are examined y comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach.

There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean BEHP surface sediment concentration in this reach is 94 ug/kg.

The surface sediment BEHP concentrations in the downtown reach are greater than the subsurface concentrations. The mean surface concentration is 418 ug/kg, while the mean subsurface concentration is 103 ug/kg.

BEHP concentrations are generally greater in surface sediments than in subsurface sediments within the Study Area as a whole. The mean surface sediment concentration in the Study Area is 1,050 ug/kg and the mean subsurface sediment concentration is 345 ug/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-24 shows yhat mean concentrations are greater in the nearshore areas than in the navigation channel and the eastern nearshore zone is greater than the western nearshore zone. It also shows that concentrations are generally grerater in the surface sediment than the subsurface sediment.

In the eastern nearshore zone, surface sediment concentrations are greater than subsurface sediment in all river miles zones except for RM 5 to 6 where the mean concentrations are about the same, and RM 8 to 9 where the mean concentration in subsurface is about twice that of the surface mean (Tables 5.2-3 and 5.2-4). The maximum surface and subsurface samples in the eastern nearshore zone are both found in Swan Island Lagoon.

In the western nearshore zone, surface sediment concentrations are also greater than subsurface sediment in all river miles zones except RM 5 to 6 where the mean subsurface conentration is an order of magnitude greater than the mean surface concentration, and RM 7 to 8 where the mean subsurface concentration is about the same as the mean surface concentration. The maximum surface sample in the western nearshore zone is located between RM 7 and 8 while the maximum subsurface sample is located between RM 5 and 6.

The navigation channel zone also had surface sediment concentrations that were greater than subsurface sediment. The only notable area where mean subsurface sediment concentration was greater than the mean surface sediment concentrations was RM 7 to 8 where the subsurface was about three times the surface concentration. The maximum surface and subsurface sampes in the navigation channel, however, are both found in RM 10 to 11.

The surface sediment concentrations in the downstream reach were greater than the subsurface concentrations. The mean surface concentration is 64 ug/kg, while the mean subsurface concentration is 11 ug/kg.

5.2.6.5 BEHP Sediment Relationships by River Reach

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Comparisons of the BEHP data sets between the river reaches (Upriver, Downtown, Study Area, and Downstream) are discussed using the summary statistics and box-whisker plots.

Surface Sediment

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There were far more data points in the Study Area reach (1,513) than in the other river reaches (Upriver – 72; Downtown – 96; and Downstream – 21) which may affect the comparability of the data sets.

The Study Area reach has the highest median of 140 ug/kg (Table 5.2-1), followed by the Downtown reach meadian of 76 J ug/kg (Table 5.2-15a), the Downstream reach median of 57 ug/kg (Table 5.2-19), and the Upriver reach median of 40 ug/kg (Table 5.2-11). These tables also show that the means of the data sets result in a slightly different order of the reaches: Study Area reach (1,050 ug/kg), Downtown reach (418 ug/kg); Upriver reach (94 ug/kg); and Downstream reach (64 ug/kg).

A box-whisker plot showing the relationship of BEHP in sediment between the river reaches is presented in Figure 5.2-24. The box-whisker plots were plotted using both detet and nondetect data. The whiskers on the low end are indicative of the detection limits; however, due to the large number of samples in this data set with high nondetect values, there will be an effect of upward skewing of the data causing comparisons of data sets to be less reliable.

The relative dispersion of the Downstream data set is comparatively small. The length of the inner quartile for the Study Area is small compared to the whiskers, sugguestion a middle clustering of data about the median with a long upper whisker, representing a large dispersion of the relative data in the upper range of the data set. This is also seen in the Downtown data set, and to a lesser extent in the Upriver data set. The Upriver data set exhibits downward skewness.

Comparing the surface ddata sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap in the Study Area and Downstream data sets, followed by the Upriver and Study Area, Downtown and Downstream, Downtown and Study Area, Upriver and Downtown, and Upriver and Downstream. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and median of the Upriver reach overlaps with the spread and medians of the Downtown and Downstream data sets; hence, there is no difference between these two data sets. Likewise, the spread and median of the Downtown and Study Area reaches overlap so there is no difference between those data sets. The spead of the Upriver reach overlaps the spread of the Study Area reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Study Area are greater than the data points collected Upriver. This is also observed between the Downtown reach and the Downstream reach indicating that the majority of the data in the Downtown reach is greater than the data points collected Downstream. There is no overlap between the Study Area reach and Downstream reach spreads; consequently, the Study Area data set is greater than the Downstream data set.

Subsurface Sediment

The Upriver subsurface data set is comprised of only three nondetected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like the surface sediment, the Study Area reach has far more data points (1,591) than the other reaches (Downtown – 64; and Downstream – 17) which may have an effect on the comparison of the data sets.

The Study Area reach has the highest median of 95 ug/kg (Table 5.2-2), followed by the Downtown reach median of 38 J ug/kg (Table 5.2-15a), and the Downstream reach median of 8.2 J ug/kg (Table 5.2-20). These tables also show the means of the data set result in the same order of reaches: Study Area reach (345 ug/kg), Downtown reach (103 ug/kg), and Downstream reach (11 ug/kg).

A box-whisker plot (Figure 5.2-24) showing the relationship of BEHP in sediment between the river reaches were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the Downstream data set is comparatively small. The length of the inner quartile for the Study Area reach is small compared to the whiskers, suggesting a middle clustering of data about the median. The long upper whisker of the Study Area reach represents a large dispersion of the relative data in the upper range of the data set. The Downstream data set exhibits downward skewness.

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Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downstream and Study Area data sets, followed by the Downtown and Study Area data sets, and the Downtown and Downstream data sets. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of the Downtown reach and the Downstream reach overlap each other; hence there is no difference between these data sets. The spread of the Downtown reach overlaps the spread of the Study Area reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Study Area are greater than the data points collected Downtown. This is also observed between the Downtown reach and the Downstream reach indicating that the majority of the data in the Downtown reach is greater than the data points collected Downstream. There is no overlap between the Study Area reach and Downstream reach spreads; consequently, the Study Area data set is greater than the Downstream data set.

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~~5.13.20.9~~5.2.7 Total Chlordanes in Sediment

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Several data presentations for the surface and subsurface total chlordanes data set withi the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. The distribution of total chlordanes concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-19; concentrations with depth at subsurface stations are depicted on Maps 5.2-20a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-25 and 5.2-26 present scatter plots of the total chlordanes data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for total chlordanes in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respecteively. Tables 5.2-9 and 5.2-10 present total chlordanes data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-27.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the

Downtown reach surface sediment samples are presented in Map 5.2-42. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-2-; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-28.

5.2.7.1 Total Chlordanes Data Set

The Study Area data set of total chlordanes concentrations includes 1,193 surface samples and 1,214 subsurface samples. The Upriver data set includes 77 surface samples and 3 subsurface samples. The downtown data set includes 145 surface samples and 94 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples. There are several nondetect values that exceed detected values (Figures 5.2-25 and 5.2-26); thus, the majority of this discussion will focus on the detected values only since meaningful conclusions cannot be drawn from the elevated nondeted values.

5.2.7.2 Total Chlordanes in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total chlordanes was analyzed in 77 surface sediment samples and detected in 38 samples within the Upriver reach (detection frequency of 49 percent), with detected concentrations ranging from 0.06 J ug/kg to 1.5 ug/kg (Table 5.2-11). Table 5.2-13 shows that there are two data points greater than 1 ug/kg. The other 36 samples were all detected at concentrations less than 1 ug/kg. The mean total chlordanes concentration in this reach is 0.39 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

Total chlordanes was analyzed in 145 surface sediment samples and detected in 110 samples within the Downtown reach (detection frequency of 76 percent), with detected concentrations ranging from 0.04 J ug/kg to 23 J ug/kg (Table 5.2-15a) and a mean concentration of 1.3 ug/kg. The total chlordanes concentrations in surface sediment varied along the Downtown reach (Map 5.2-42). The map shows that the majority of the samples are less than 1 ug/kg in this reach and that there is no discernable pattern to the surface sediment samples greater than this value.

Table 5.2-17 shows that there are two samples greater than 10 ug/kg. The majority of the data, 98 percent of the detected data set, is detected at concentrations less than 10 ug/kg: 35 samples were detected in the range of 1 to 10 ug/kg and 73 data points were detected at concentrations less than 1 ug/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the total chlordanes data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Total chlordanes was analyzed in 1,193 surface sediment samples and detected in 761 samples within the Study Area (detection frequency of 64 percent) with concentrations ranging from 0.03 J ug/kg to 669 NJ ug/kg (Table 5.2-1). The mean total chlordanes concentration of surface sediment in the Study Area is 5 ug/kg. Total chlordanes concentrations in surface sediment varied along the Study Area (Figure 5.2-25).

Four prominent peaks (>10 ug/kg) in the surface sediment are identified in the eastern nearshore zone (Figure 5.2-25). Clusters of concentrations greater than 10 µg/kg occur at RM 3.8, RM 5.5 ~~(Willamette Cove)~~, in Swan Island Lagoon, at RM 11 (Figure 5.2-25 and Map 5.2-19). The highest surface concentration detected in the eastern nearshore zone (60 ug/kg) was found at Station GCA11E at RM 11. Another sample detected at a concentration greater than 10 ug/kg is located at RM 2.8. Mean total chlordanes concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 1.15 ug/kg for RM 2 to 3; 1.48 ug/kg for RM 3 to 4; 2.37 ug/kg for RM 5 to 6; 2.75 ug/kg in Swan Island Lagoon; and 11.4 ug/kg for RM 11 to 11.8.

The western nearshore zone has detected total chlordanes concentrations that exceed 10 ug/kg from RM 5.8 through 9. It appears that there may be a prominent peak at RM 8.8 (Figure 5.2-21), but the remainder of the elevated concentrations appear to be more dispersed. ~~Overall, detected concentrations of total chlordanes were below 5 µg/kg throughout most of the Study Area (Maps 5.1-13 and 5.1-14a–m, see frequency plot inset) and, with few exceptions, were generally lower along the navigation channel (Figures 5.1-17 and 5.1-18; Tables 5.1-1 and 5.1-2). Sediment concentrations greater than 5 µg/kg were detected at several locations throughout the Study Area, but occurred most extensively along the western nearshore zone between approximately RM 6 and 7.4 (Maps 5.1-13 and 5.1-14a–m).~~

~~Frequencies of detection were 64 percent and 55 percent, respectively, for surface and subsurface samples. Approximately ninety-five percent of the surface samples were below 12.2 JV µg/kg.~~ The maximum surface concentration (669 NJ ug/kg) was found at Station G355 (RM 7.3W). ~~Another cluster of concentrations greater than 5 µg/kg in surface and subsurface samples occurred at RM 8.8W and at the head of the International Terminals Slip (RM 3.7E; some areas have subsequently been dredged).~~ Mean concentrations (Table 5.2-7) for this area in the western nearshore zone are: 1.75

ug/kg for RM 5 to 6; 12.5 ug/kg for RM 6 to 7; 24.9 ug/kg for RM 7 to 8; and 28.9 ug/kg for RM 8 to 9. There were no samples detected in the navigation channel exceeding 10 ug/kg.

Table 5.2-9 shows that there are three detected data points in surface sediment greater than 100 ug/kg and there are 46 detected values between 10 and 100 ug/kg. Surface sediment values greater than 10 ug/kg accounts for six percent of the detected data set. One third the detected data set (270 samples; 35 percent of the detected data set) were detected at concentrations between 1 and 10 ug/kg. Over half the detected data set (442 samples; 58 percent) were detected at concentrations less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

Total chlordanes was analyzed in 25 surface sediment samples and detected in 15 samples within the Downstream reach (detection frequency of 60 percent), with concentrations ranging from 0.07 NJ ug/kg to 4.5 J ug/kg (Table 5.2-19). Table 5.2-21 shows that there are three samples greater than 1 ug/kg. The majority of the detected data set (12 samples) was detected at concentrations less than 1 ug/kg. The mean total chlordanes concentration in this reach is 0.8 ug/kg.

5.2.7.3 Total Chlordanes in Subsurface Sediment

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Upriver Reach (RM 15.3 to 26)

Total chlordanes concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 0.2 ug/kg to 1.3 ug/kg; the average concentration for this reach is 0.89 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

Total chlordanes was analyzed in 94 subsurface sediment samples and detected in 51 samples within the Downtown reach (detection frequesncy of 54 percent), with concentrations ranging from 0.09 J ug/kg to 54 ug/kg (Table 5.2-16a) and a mean concentration of 3.2 ug/kg. Table 5.2-17 shows that there are two values detected above 10 ug/kg. About half of the detected data set (26 samples; 51 percent) were deteted at concentrations between 1 and 10 ug/kg. The remaining data set (23 samples) were detected at concentrations less than 1 ug/kg. None of the subsurface samples were analyzed in the vicinity of the Zidell facility.

Study Area Reach (RM 1.9 to 11.8)

Of the 1,214 subsurface samples analyzed for total chlordanes, 648 were detected (53 percent detection frequency) with concentrations ranging from an estimated 0.04 J µg/kg to an estimated 2,330 J µg/kg (Table 5.2-2) and a mean concentration of 20 ug/kg. Similar to surface sediment, total chlordanes concentrations in the subsurface also varied within the Study Area (Figure 5.2-26; Maps 5.2-20a-o).

The same four prominent peaks (>10 ug/kg) identified in the surface sediment are identified in the subsurface samples within the eastern nearshore zone (Figure 5.2-26).

Clusters of concentrations greater than 10 µg/kg occur at RM 3.8, RM 5.5 ~~(Willamette Cove)~~, in Swan Island Lagoon, at RM 11 (Figure 5.2-26 and Map 5.2-20a-o). The highest subsurface concentration detected in the eastern nearshore zone (490 ug/kg) was found at Station C092 at RM 3.8. Another sample detected at a concentration greater than 10 ug/kg is located at RM 2.2. Mean total chlordanes concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 2.26 ug/kg for RM 2 to 3; 31.2 ug/kg for RM 3 to 4; 4.67 ug/kg for RM 5 to 6; 15.5 ug/kg in Swan Island Lagoon; and 23.5 ug/kg for RM 11 to 11.8.

The western nearshore zone has detected total chlordanes concentrations that exceed 10 ug/kg from RM 4.5 through 9. It appears that there may be a prominent peak at RM 8.8 (Figure 5.2-21), but the remainder of the elevated concentrations appear to be more dispersed. A sample collected at RM 8.8 contained the highest subsurface concentration of total chlordanes (2,330 J ug/kg) in the Study Area (Station C455 in the interval of 30–152 cm bml). Mean concentrations (Table 5.2-8) for this area in the western nearshore zone are: 5.79 ug/kg for RM 4 to 5; 17.2 ug/kg for RM 5 to 6; 18.9 ug/kg for RM 6 to 7; 68.5 ug/kg for RM 7 to 8; and 61.4 ug/kg for RM 8 to 9.

~~This same core sample contained the maximum concentrations of total PCBs and total PCDD/Fs in the Study Area.~~

There are three prominent peaks in the navigation channel zone at RM 6.5, 10.3 and 11.3. The peak at RM 6.5 is most likely associated with the western nearshore zone (Map 5.2-20g) and the peak at RM 11.3 is most likely associated with the eastern nearshore zone (Maps 5.2-20n,o). There is no discernable pattern the the concentrations found at RM 10.3 since samples are elevated throughout the navigation channel, although it appears that more elevated samples are located near the western nearshore area (see Map 5.2-20l). The mean concentrations for these areas are: 1.94 ug/kg for RM 6 to 7; 2.83 ug/kg for RM 10 to 11, and 7.82 for RM 11 to 11.8 (Table 5.2-6).

Table 5.2-9 shows that there is one data point greater than 1,000 ug/kg and 19 detected values between 100 and 1,000 ug/kg, which are primarily located within the peak areas discussed above. An additional 67 samples were detected at concentrations between 10 and 100 ug/kg. Subsurface sediment samples greater than 10 ug/kg accounts for 13 percent of the detected data set. Almost half of the detected data set (316 samples; 49 percent) is between 1 and 10 ug/kg. The remaining 245 data points (38 percent) is comprised of concentrations less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

Total chlordanes was analyzed in 26 subsurface sediment samples and detected in 5 samples within the Downstream reach (detection frequency of 19 percent), with concentrations ranging from 0.75 NJ ug/kg to 2.2 NJ ug/kg (Table 5.2-20). Tables 5.2-21 shows that there are four samples detected at concentrations greater than 1 ug/kg and one sample detected at a concentration less than 1 ug/kg. The mean total chlordanes concentration in this reach is 1.5 ug/kg.~~Except for elevated detections from RM 10 to 10.2 and RM 11.2 to 11.6, peaks in the navigation channel were typically located near elevated concentrations in the nearshore.~~

5.2.7.4 Total Chlordanes Surface and Subsurface Sediment Relationships

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Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean total chlordanes surface sediment concentration in this reach is 0.39 ug/kg (Table 5.2-11).

The subsurface sediment concentrations in the downtown rach were greater than the surface concentrations. The mean surface concentration is 1.3 ug/kg, while the mean subsurface sediment concentration is 3.2 ug/kg (Tables 5.2-15a and 5.2-16a).

Total chlordanes are also generally greater in the subsurface sediments than in surface sediments within the Study Area as a whole. The mean surface sediment concentration is 5 ug/kg and the mean subsurface sediment concentration is 20 ug/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-27 shows that mean concentrations are greater in the nearshore areas than in the navigation channel and the western nearshore zone is greater than the eastern nearshore zone. It also shows that concentrations are generally greater in the subsurface sediment than in surface sediment.

In the eastern nearshore zone, subsurface sediment is greater than surface sediment in all river mile zones except RM 10 to 11. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles excpt RM 1.9 to 3 and possibly RM 9 to 10. The subsurface sediment concentrations in the navigation channel are generally greater than the surface sediment concentrations except from RM 1.9 to RM 4.

Areas where subsurface sediment concentrations are elevated generally align with the locations where surface sediment concentrations are elevated, although not to the same extent. The most prominent areas are RM 6 to 7 and RM 7 to 8 in the western nearshore zones. Additional areas with elevated concentrations are located from RM 3 to 4 in the eastern nearshore zone, RM 5 to 6 in the western nearshore zone, RM 6 to 7 in the eastern nearshore zone, Swan Island Lagoon, and RM 11 to 11.8 in the eastern nearshore zone (Figure 5.2-27).

The subsurface sediment concentrations in the downstream reach were greater than surface concentrations. The mean surface concentration is 0.8 ug/kg, while the mean subsurface concentration is 1.5 ug/kg (Tables 5.2-19 and 5.2-20)

5.2.7.5 Total Chlordanes Sediment Relationship by River Reach

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Comparisons of the total chlordanes data sets between the river reaches (Upriver, Downtown, Study Area, and Downstream) are discussed using the summary statistics and box-whisker plots.

Surface Sediment

There were far more data points in the Study Area reach (1,193) than in the other river reaches (Upriver – 77; Downtown – 145; and Downstream – 25) which may affect the comparability of the data sets.

The Study Area reach has the highest median of 0.84 NJ ug/kg (Table 5.2-1), followed by the Downtown reach meadian of 0.55 J ug/kg (Table 5.2-15a), the Upriver reach median of 0.34 J ug/kg (Table 5.2-11), and the Downstream reach median of 0.29 ug/kg (Table 5.2-19). These tables also show that the means of the data sets result in a slightly different order of the reaches: Study Area reach (5 ug/kg), Downtown reach (1.3 ug/kg); Downstream reach (0.8 ug/kg); and Upriver reach (0.39 ug/kg).

A box-whisker plot showing the relationship of total chlordanes in sediment between the river reaches is presented in Figure 5.2-28. The box-whisker plots were plotted using both detet and nondetect data. The whiskers on the low end are indicative of the detection limits; however, due to the large number of samples in this data set with high nondetect values, there will be an effect of upward skewing of the data causing comparisons of data sets to be less reliable.

The relative dispersion of the Upriver data set, and to some extent the Downstream data set, is comparatively small. The length of the inner quartile for the Study Area is small compared to the whiskers, sugguestion a middle clustering of data about the median with a long upper whisker, representing a large dispersion of the relative data in the upper range of the data set. This is also seen to a lesser extent in the Downtown data set. The Upriver data set exhibits upward skewness while the other data sets exhibit downward skewness.

Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap in the Upriver and Study Area data sets, followed by the Upriver and Downstream, Downtown and Downstream, Downtown and Study Area, Study Area and Downstream, and Upriver and Downtown. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and median of the Upriver reach overlaps with the spread and median of the Downtown data set; hence, there is no difference between these two data sets. Likewise, the spread and median of the Downtown and Downstream reaches and Study Area and Downstream reaches overlap so there is no difference between those data sets. The spead of the Upriver reach overlaps the spread of the Study Area reach and Downstream; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Study Area and Downstream are greater than the data points collected Upriver. This is also observed between the Downtown reach and the Study Area reach indicating that the majority of the data in the Study Area reach is greater than the data points collected Downtown.

Subsurface Sediment

The Upriver subsurface data set is comprised of only three nondetected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like the surface sediment, the Study Area reach has far more data points (1,214) than the other reaches (Downtown – 94; and Downstream – 26) which may have an effect on the comparison of the data sets.

The Downstream reach has the highest median of 1.6 J ug/kg (Table 5.2-20), followed by the Study Area reach median of 1.57 J ug/kg (Table 5.2-2), and the Downtown reach median of 1.3 ug/kg (Table 5.2-16a). These tables also show the means of the data set result in a different order of reaches: Study Area reach (20 ug/kg), Downtown reach (3.2 ug/kg), and Downstream reach (1.5 ug/kg).

A box-whisker plot (Figure 5.2-24) showing the relationship of total chlordanes in sediment between the river reaches were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the Downstream data set is comparatively small. The length of the inner quartile for the Study Area reach is small compared to the whiskers, suggesting a middle clustering of data about the median. The long upper whisker of the Study Area reach represents a large dispersion of the relative data in the upper range of the data set. The Downtown data set exhibits this to a lesser extent. The Downtown and Downstream data sets exhibits downward skewness while the Study Area data set exhibits upward skewness.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downtown and Downstream data sets, followed by the Downstream and Study Area data sets, and the Downtown and Study Area data sets. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of the Downtown reach and the Study Area reach overlap each other; hence there is no difference between these data sets. This is also observed between the Study Area and Downstream data sets. The spead of the Downtown reach overlaps the spread of the Downstream reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Downstream are greater than the data points collected Downtown.

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~~5.13.20.10~~5.2.8 Aldrin and Dieldrin in Sediment

The insecticides, aldrin and dieldrin, have similar chemical structures and are discussed together here because aldrin quickly breaks down into dieldrin in the living systems (i.e., plants and animals) and environment (i.e., soils due to photolysis); however, aldrin is not converted to dieldrin under anaerobic conditions. Consequently, it is unlikely that aldrin is converted to dieldrin in sediments, but may do so within other media that will be discussed in subsequent sections.

Several data presentations for the surface and subsurface aldrin and dieldrin data sets withi the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. The distribution of aldrin and dieldrin concentrations at each surface sediment sampling station throughout the Study Area is depicted on Maps 5.2-21 and 5.2-23; concentrations with depth at subsurface stations are depicted on Maps 5.2-22a-o and 5.2-24a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-29 and 5.2-30 present scatter plots of the aldrin data set for surface and subsurface sediment in the Study Area, respectively. Figures 5.2-33 and 5.2-34 present scatter plots of the aldrin data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for aldrin and dieldrin in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respecteively. Tables 5.2-9 and 5.2-10 present aldrin and dieldrin data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figures 5.2-31 (for aldrin) and 5.2-35 (for dieldrin).

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Maps 5.2-43 and 5.2-44. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-

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19 and 5.2-2-; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, box-whisker plots comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach are presented in Figures 5.2-32 (for aldrin) and 5.2-36 (for dieldrin).

5.2.8.1 Aldrin and Dieldrin Data Sets

The Study Area data set of aldrin concentrations includes 1,146 surface samples and 1,272 subsurface samples. The Upriver data set includes 77 surface samples and 3 subsurface samples. The downtown data set includes 145 surface samples and 94 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples. There are several nondetect values that exceed detected values (Figures 5.2-29 and 5.2-30); thus, the majority of this discussion will focus on the detected values only since meaningful conclusions cannot be drawn from the elevated nondeted values.

The Study Area data set of dieldrin concentrations includes 1,190 surface samples and 1,208 subsurface samples. The Upriver data set includes 77 surface samples and 3 subsurface samples. The downtown data set includes 145 surface samples and 94 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples. There are several nondetect values that exceed detected values (Figures 5.2-33 and 5.2-34); thus, the majority of this discussion will focus on the detected values only since meaningful conclusions cannot be drawn from the elevated nondeted values.

5.2.8.2 Aldrin and Dieldrin in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Aldrin was analyzed in 77 surface sediment samples and detected in seven samples within the Upriver reach (detection frequency of nine percent), with detected concentrations ranging from 0.17 J ug/kg to 0.55 ug/kg (Table 5.2-11). Table 5.2-13 shows that all the data points are less than 1 ug/kg. The mean aldrin concentration in this reach is 0.33 ug/kg.

Dieldrin was also analyzed in the same 77 surface sediment samples, but was detected in ten samples within the Upriver reach (detection frequency of 13 percent), with detected concentrations ranging from 0.09 NJ ug/kg to 0.4 ug/kg (Table 5.2-11). Table 5.2-13 shows that all the data points are less than 1 ug/kg. The mean dieldrin concentration in this reach is 0.2 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

Aldrin was analyzed in 145 surface sediment samples and detected in 22 samples within the Downtown reach (detection frequency of 15 percent), with detected concentrations ranging from 0.07 J ug/kg to 0.7 NJ ug/kg (Table 5.2-15a) and a mean concentration of

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0.26 ug/kg. Table 5.2-17 shows that all the data points were detected at concentrations less than 1 ug/kg.

Dieldrin was also analyzed in the same 145 surface sediment samples but was detected in only 14 samples within the Downtown reach (detection frequency of ten percent) with detected concentrations ranging from 0.04 J ug/kg to 1.1 ug/kg (Table 5.2-15a) and a mean concentration of 0.27 ug/kg. Table 5.2-17 shows that only one sample was detected at a concentration greater than 1 ug/kg. The remaining 13 samples were detected at concentrations less than 1 ug/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the aldrin or dieldrin data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Aldrin was analyzed in 1,146 surface sediment samples and detected in 268 samples within the Study Area (detection frequency of 23 percent) with concentrations ranging from 0.003 J ug/kg to 691 J ug/kg (Table 5.2-1). The mean aldrin concentration of surface sediment in the Study Area is 5 ug/kg. Aldrin concentrations in surface sediment varied along the Study Area (Figure 5.2-29).

Dieldrin was analyzed in 1,190 surface sediment samples and was detected in 252 samples within the Study Area (detection frequency of 21 percent) with concentrations ranging from 0.008 ug/kg to 356 J ug/kg (Table 5.2-1). The mean dieldrin concentration of surface sediment within the Study Area is 3 ug/kg. Dieldrin concentrations in surface sediment also varied along the Study Area (Figure 5.2-33).

There were no detected concentrations of aldrin greater than 10 ug/kg in the surface sediment within the eastern nearshore zone (Figure 5.2-29). Concentrations greater than 1 ug/kg are noted in the eastern nearshore zone from RM 2 to 4, RM 5.8 to 6.2, and in Swan Island Lagoon. The highest surface concentration of aldrin detected in the eastern nearshore zone (6 ug/kg) is located at Station PSY01 in Swan Island Lagoon. Mean aldrin concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 0.9 ug/kg for RM 1.9 to 3; 0.5 ug/kg for RM 3 to 4; 0.9 ug/kg for RM 5 to 6; and 1.0 ug/kg in Swan Island Lagoon.

Detected concentrations of dieldrin greater than 10 ug/kg in surface sediment is noted only in Swan Islan Lagoon (Figure 5.2-33). Concentrations greater than 1 ug/kg are located in the same general area as aldrin with the addition of RM 11 to 11.8 in the eastern nearshore zone. The highest surface concentration of dieldrin detected in the eastern nearshore zone (22 ug/kg) is located at Station M0201 in Swan Island Lagoon. Mean concentrations of dieldrin (Table 5.2-3) for these areas in the eastern nearshore zone are: 0.8 ug/kg for RM 1.9 to 3; 0.2 ug/kg for RM 3 to 4; 1.2 ug/kg for RM 5 to 6; 4.4 ug/kg for Swan Island Lagoon; and 4.4 ug/kg for RM 11 to 11.8.

The western nearshore zone has detected aldrin concentrations that exceed 10 ug/kg from RM 6.8 through 7.2 and at RM 8.8. Prominent peaks (>100 ug/kg) are noted at RMs 7.3 and 8.8 (Figure 5.2-29). The maximum surface concentration of aldrin (691 J ug/kg) is located at Station G355 (RM 7.3W). Concentrations greater than 1 ug/kg are noted from RM 3 through RM 10 in this region of the river. Mean concentrations (Table 5.2-7) for this area in the western nearshore zone are: 0.6 ug/kg for RM 3 to 4; 0.6 for RM 4 to 5; 1.0 ug/kg for RM 5 to 6; 3.4 ug/kg for RM 6 to 7; 40 ug/kg for RM 7 to 8; 14 ug/kg for RM 8 to 9; and 1.0 ug/kg for RM 9 to 10.

Detected concentrations of dieldrin in the western nearshore zone exceeding 10 ug/kg are located at RM 6.3, RM 7.3 and RM 8.3 through 8.8. A prominent peak (>100 ug/kg) is noted at RM 8.8 (Figure 5.2-33). The maximum surface concentration of dieldrin (356 J ug/kg) is located at Station G453 (RM 8.8W). Concentrations greater than 1 ug/kg are noted at RM 3.3, from RM 5.5 through 9.8, and at RM 11.3 in this region of the river. Mean concentrations (Table 5.2-7) for these areas in the western nearshore zone are: 0.3 ug/kg for RM 3 to 4; 0.4 ug/kg for RM 5 to 6; 1.8 ug/kg for RM 6 to 7; 2.9 ug/kg for RM 7 to 8; 29 ug/kg for RM 8 to 9; and 2.5 ug/kg for RM 11 to 11.8.

There were no samples of aldrin or dieldrin detected in the navigation channel exceeding 10 ug/kg (Figures 5.2-29 and 5.2-33). Concentrations of aldrin greater than 1 ug/kg are noted from RM 2 to 3, RM 5 to 7.5, and at RM 9.3. Mean aldrin concentrations (Table 5.2-5) for these areas in the navigation channel are: 0.7 ug/kg for RM 1.9 to 3; 1.2 ug/kg for RM 5 to 6; 0.81 ug/kg for RM 6 to 7; and 0.7 ug/kg for RM 9 to 10. Concentrations of dieldrin greater than 1 ug/kg are noted at RM 5.6 and RM 6.4. Mean dieldrin concentration for these areas in the navigation channel are: 0.7 for RM 5 to 6; and 0.5 ug/kg for RM 6 to 7.

Table 5.2-9 shows that there are two detected data points of aldrin in surface sediment greater than 100 ug/kg and there are 12 detected values between 10 and 100 ug/kg. Surface sediment values greater than 10 ug/kg accounts for five percent of the detected data set. One quarter the detected data set (67 samples) were detected at concentrations between 1 and 10 ug/kg. Over half the detected data set (187 samples; 70 percent) were detected at concentrations less than 1 ug/kg.

Table 5.2-9 shows that there is only one detected data point of dieldrin in surface sediment greater than 100 ug/kg and there are six detected values between 10 and 100 ug/kg. Surface sediment values greater than 10 ug/kg accounts for three percent of the detected data set. Another 33 data points (13 percent of the detected data set) were detected at concentrations ranging from 1 to 10 ug/kg. The majority of the detected samples (212 samples; 84 percent) were detected at concentrations less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

Aldrin was analyzed in 25 surface sediment samples and detected in 3 samples within the Downstream reach (detection frequency of 12 percent), with concentrations ranging from 0.37 J ug/kg to 0.4 J ug/kg (Table 5.2-19). Table 5.2-21 shows that there are three samples less than 1 ug/kg. The mean aldrin concentration in this reach is 0.4 ug/kg.

Dieldrin was also analyzed in the same 25 surface sediment samples, but was detected in only one sample within the Downstream reach at a concentration of 0.07 J ug/kg.

5.2.8.3 Aldrin and Dieldrin in Subsurface Sediment

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Upriver Reach (RM 15.3 to 26)

Aldrin and dieldrin were analyzed in three subsurface sediment samples between RM 15.4 and 16 and were not detected any samples within the Upriver reach. The maximum detect level for aldrin was 0.2 U ug/kg and the maximum detect level for dieldrin was 0.036 U ug/kg (Table 5.2-12).

Downtown Reach (RM 11.8 to 15.3)

Aldrin was analyzed in 94 subsurface sediment samples and detected in 8 samples within the Downtown reach (detection frequency of nine percent), with detected concentrations ranging from 0.08 J ug/kg to 1.7 ug/kg (Table 5.2-15a) and a mean concentration of 0.41 ug/kg. Table 5.2-17 shows that one data point was detected at a concentration greater than 1 ug/kg. The remaining seven samples are all detected at concentrations less than 1 ug/kg.

Dieldrin was also analyzed in the same 94 subsurface sediment samples but was detected in only 4 samples within the Downtown reach (detection frequency of four percent) with detected concentrations ranging from 0.29 J ug/kg to 16 J ug/kg (Table 5.2-15a) and a mean concentration of 7 ug/kg. Table 5.2-17 shows that one sample was detected at a concentration greater than 10 ug/kg, one sample was detected at a concentration between 1 and 10 ug/kg and one sample was detected at a concentration less than 1 ug/kg.

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In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. None of the aldrin or dieldrin data was excluded from the Downtown reach.

Study Area Reach (RM 1.9 to 11.8)

Aldrin was analyzed in 1,172 subsurface sediment samples and detected in 135 samples within the Study Area (detection frequency of 12 percent) with concentrations ranging from 0.11 J ug/kg to 1,340 J ug/kg (Table 5.2-1). The mean aldrin concentration of surface sediment in the Study Area is 5 ug/kg. Aldrin concentrations in subsurface sediment varied along the Study Area (Figure 5.2-30).

Dieldrin was analyzed in 1,208 subsurface sediment samples and was detected in 77 samples within the Study Area (detection frequency of six percent) with concentrations ranging from 0.04 NJ ug/kg to 100 J ug/kg (Table 5.2-1). The mean dieldrin concentration of subsurface sediment within the Study Area is 4 ug/kg. Dieldrin concentrations in subsurface sediment also varied along the Study Area (Figure 5.2-34).

There were no detected concentrations of aldrin greater than 10 ug/kg in the subsurface sediment within the eastern nearshore zone (Figure 5.2-30). Concentrations greater than 1 ug/kg are noted in the eastern nearshore zone from RM 1.9 to 5.6 and at RM 11.2. The highest subsurface concentration of aldrin detected in the eastern nearshore zone (3.81 NJ ug/kg) is located at Station C019-1 at RM 2.3. Mean aldrin concentrations (Table 5.2-4) for these areas in the eastern nearshore zone are: 1.0 ug/kg for RM 1.9 to 3; 0.7 ug/kg for RM 3 to 4; 0.7 ug/kg for RM 4 to 5; 0.9 ug/kg for RM 5 to 6; and 1.8 ug/kg for RM 11 to 11.8.

There is a prominent peak of dieldrin (100 ug/kg) noted at RM 3.7 (Station C092; 30–152 cm bml) at the head of the International Terminals Slip in the eastern nearshore zone (Figure 5.2-34; Table 5.2-4). There were no other detected concentrations of dieldrin greater than 10 ug/kg in the subsurface sediment within the eastern nearshore zone. Only two samples were detected in subsurface sediment greater than 1 ug/kg: one at RM 2.2 (1.1 NJ ug/kg) and another at RM 6.7 (1.12 NJ ug/kg).

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~~Detected concentrations of both chemicals were generally less than 1 µg/kg (Maps 5.1-15 through 5.1-18, see frequency plot inset), though higher concentrations occurred at several locations scattered along the nearshore zones and navigation channel (Figures 5.1-19 through 5.1-22).~~

~~Frequencies of detection for aldrin were low, 23 percent for surface samples and only 13 percent for subsurface samples (Tables 5.1-1 and 5.1-2). Ninety-five percent of the surface samples were below 10.6 JV µg/kg.~~ The most prominent area of detected aldrin concentrations was in the western nearshore zone at RM 7.4 (Figure 5.2-30), where the maximum ~~surface (Station G355) and~~ subsurface (Station C356, 136–256 cm bml) concentration (1,340 J ug/kg)~~s~~ w~~ere~~as detected. ~~Concentrations greater than 1 µg/kg extended downstream along the western shoreline to approximately RM 5.2 (Maps 5.1-15 and 5.1-16a–m).~~

Two other prominent aldrin peaks (>100 ug/kg ~~are shown by the data, one indicated by concentrations exceeding 100 µg/kg~~) in ~~surface and~~ subsurface samples are located at RM 6.1 and RM 8.8~~, the other indicated by concentrations approaching 100 µg/kg in the subsurface from approximately RM 6 to 6.5~~ (Figure~~s~~ ~~5.1-19 and 5.1-20~~5.2-30). Concentrations greater than 10 ug/kg are noted from RM 6.1 through RM 8.8 and detected concentrations greater than 1 ug/kg extend from 4.5 to RM 8.8. Mean aldrin concententrations (Table 5.2-8) for these areas in the western nearshore zone are: 0.9 ug/kg for RM 4 to 5; 1.9 ug/kg for RM 5 to 6; 29 ug/kg for RM 6 to 7; 73 ug/kg for RM 7 to 8; and 68 ug/kg for RM 8 to 9.

Detected concentrations of dieldrin greater than 10 ug/kg are seen in the western nearshore zone between RM 6 and 8.8 (Figure 5.2-34). There are no concentrations greater than 1 ug/kg outside this area. Mean dieldrin concentrations (Table 5.2-8) for these areas in the western nearshore zone are: 4.5 ug/kg for RM 6 to 7; 4.0 ug/kg for RM 7 to 8; and 17.3 ug/kg for RM 8 to 9.~~Some of these data are N-qualified.~~

Aldrin concentrations greater than 10 ug/kg are identified at RM 6.4 and concentrations above 1 µg/kg were detected from RM 6 to 7 and at ~~several locations~~RM 10.3 within the navigation channel (Figure 5.2-30). The maximum concentration of aldrin (44 J ug/kg) within the navigation channel occurred ~~in the interval of 30 to 137 cm-bml~~ at core Station C29906 (~~approximately~~ RM 6.45.6 near the ~~east~~ west bank). Mean aldrin concentrations (Table 5.2-6) for these areas are: 13 ug/kg for RM 6 to 7; and 0.7 ug/kg for RM 10 to 11.~~This same interval also recorded high concentrations for PAHs, arsenic, chromium, copper, lead, mercury, zinc, and PCBs. Aldrin concentrations above 1 µg/kg were also detected in the navigation channel in the RM 11.2–11.5, 10–10.2, and 8.6–8.9 reaches.~~

~~Frequencies of detection for dieldrin were even lower, 21 percent for surface samples and only 7 percent for subsurface samples. Ninety-five percent of the surface samples were below 5.93 JV µg/kg. Dieldrin concentrations above 1 µg/kg were detected in subsurface samples collected along the eastern nearshore between RM 3.8 and 4, where the highest subsurface concentration in the Study Area was found at Station C092 (30–152 cm bml; N-qualified) at the head of the International Terminals Slip (Maps 5.1-17 and 5.1-18a–m).~~ Dieldrin concentrations greater than 10 ug/kg was detected in the navigation channel in only one sample located at Station WR-CD-40 (13 ug/kg) near RM 11.3. Concentrations above 1 µg/kg were also detected in ~~several~~ cores collected at RM 3.5, 6.1, and 11.2 in the navigation channel~~ downstream from the Broadway Bridge~~. Mean dieldrin concentrations (Table 5.2-6) for these areas are: 0.8 ug/kg for RM 3 to 4; 3.0 ug/kg for RM 6 to 7; and 5.6 ug/kg for RM 11 to 11.9.~~Along the western shoreline, dieldrin concentrations above 1 µg/kg were detected in the RM 8.5–8.8 reach, at RM 7.4, and between RM 5.7 and 6.6 (Figures 5.1-21 and 5.1-22). The maximum surface sediment concentration of dieldrin in the Study Area was found at Station G453 located in the western nearshore zone at RM 8.8.~~

Downstream Reach (RM 0 to 1.9)

Aldrin was analyzed in 26 subsurface sediment samples and detected in 3 samples within the Downstream reach (detection frequency of 12 percent), with concentrations ranging from 0.2 J ug/kg to 2.8 NJ ug/kg (Table 5.2-19). Table 5.2-21 shows that there is one sample greater than 1 ug/kg and two samples less than 1 ug/kg. The mean aldrin

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concentration in this reach is 1.2 ug/kg. Dieldrin was also analyzed in the same 25 surface sediment samples, but was not detected in any sample within the Downstream reach.

5.2.8.4 Aldrin and Dieldrin Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentration by reach and also by subareas within the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean surface sediment concentration for aldrin in this reach is 0.33 ug/kg and dieldrin is 0.2 ug/kg.

The subsurface sediment concentrations for both aldrin and dieldrin in the Downtown reach were generally greater than the surface sediment concentrations. The mean surface sediment concentration for aldrin is 0.26 ug/kg and the mean subsurface concentration is 0.41 ug/kg. Dieldrin had a mean surface sediment concentration of 0.27 ug/kg and subsurface concentration of 7 ug/kg.

Aldrin and dieldrin concentrations are also generally greater in subsurface sediments than in surface sediments within the Study Area as a whole. The mean surface sediment concentration for aldrin is 4.9 ug/kg and the mean subsurface concentration is 23 ug/kg. Dieldrin had a mean surface sediment concentration of 2.6 ug/kg and a mean subsurface concentration of 3.6 ug/kg. Figure 5.2-31 shows that mean aldrin concentrations are far greater in the western nearshore zone, followed by the navigation channel and the eastern nearshore zone. It also shows that concentrations are generally greater in subsurface sediment than in surface sediment. Figure 5.2-35 shows that mean dieldrin concentration are greater in the nearshore zones than in the navigation channel and the western nearshore zone has higher surface sediment concentrations. It also shows that concentrations in the navigation channel and eastern nearshore zone are greater in subsurface sediment while concentrations in the western nearshore zone are approximately the same.

In the eastern nearshore zone, aldrin subsurface sediment concentrations are greater than surface sediment in all river mile zones except Swan Island Lagoon. Dieldrin subsurface sediment concententrations are also greater than surface sediment in all river mile zones except RM 1.9 to 3, RM 5 to 6, and Swan Island Lagoon. In the western nearshore zone, aldrin subsurface sediment concentrations are greater than surface sediment in all river mile zones except RM 9 to 10 and RM 11 to 11.8. Dieldrin subsurface sediment concentrations are also greater than surface sediment in all river mile zones except RM 8 to 9 and RM 11 to 11.8. Conversely, the aldrin and dieldrin surface sediment concentrations in the navigation channel are generally greater than the subsurface concentrations.

Figure 5.2-32 shows that the areas with the highest aldrin concentrations in both surface and subsurface sediment are located in the western nearshore zone from RM 6 through RM 9. The navigation channel from RM 6 to 7 is also notably high and is likely associated with elevated concentrations in the western nearshore zone. Figure 5.2-36 shows that areas with the highest dieldrin concentrations are located from RM 4 to 5 in the eastern nearshore zone, where concentrations are elevated in subsurface sediment and from RM 8 to 9 in the western nearshore zone, where concentrations are elevated in both surface and subsurface sediment. Other notable areas with elevated concentrations are from RM 6 through 8 in the western nearshore zone and the associated navigation channel from RM 6 to 7, and RM 11 to 11.8, where concentrations in the nearshore zones are elevated in surface sediment while concentrations in the navigation channel are elevated in subsurface sediment.

In the Downstream reach, there was only one sample detected at a concentration of 0.069 J ug/kg in the surface sediment and no samples detected in subsurface sediment.

5.2.8.5 Aldrin and Dieldrin Sediment Relationships by River Reach

Comparisons of the aldrin and dieldrin data sets between the river reaches (Upriver, Downtown, Study Area, and Downstream) are discussed using the summary statistics tables and the bos-whisker plots.

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Surface Sediment

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There were far more data points in the Study Area reach (1,146 for aldrin and 1,190 for dieldrin) than in the other river reaches (Upriver – 77, Downtown – 145, and Downstream – 25) which may affect the comparability of the data sets.

The Study Area reach had the highest median of aldrin at 0.5 J ug/kg (Table 5.2-1), followed by the Downstream reach median of 0.4 J ug/kg (Table 5.2-19), Upriver reach median of 0.3 J ug/kg (Table 5.2-11), and Downtown reach median of 0.2 J ug/kg (Table 5.2-15a). These tables also show that the means of the data sets follow the same order of reaches: Study Area reach (4.9 ug/kg), Downstream reach (0.39 ug/kg), Upriver reach (0.33 ug/kg), and Downtown reach (0.26 ug/kg).

The Study Area reach also had the highest median of dieldrin at 0.28 J ug/kg (Table 5.2-1) followed by the Upriver and Downtown reaches that both have a median concentration of 0.16 J ug/kg (Tables 5.2-11 and 5.2-15a); the Downstream reach only had one detected concentration at 0.069 J ug/kg (Table 5.2-19). These tables show a similar pattern with the means: Study Area reach (2.6 ug/kg), Downtown reach (0.27 ug/kg), and Upriver reach (0.2 ug/kg).

A box-whisker plot showing the relationship of aldrin in sediment between the river reaches is presented in Figure 5.2-32. The box-whisker plots use both detect and nondetect data. The whiskers on the low end are indicative of the lower detection limits for the data set. The relative dispersion of the Study Area data set is comparatively large. The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative dtata in the upper range of the data set. This is also seen to a lesser extent in the Downstream data set. The Upriver and Downtown data sets exhibit upward skewness while the Study Area and Downstream data sets exhibit downward skewness. It should be noted that the number of elevated detection limits in the Study Area reach will have an effect of skewing the data upward causing the comparisons of other data sets to this one less reliable.

Comparing the aldrin data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downtown and Downstream data sets, followed by the Downtown and Study Area, Upriver and Downtown, Upriver and Study Area, Upriver and Downstream, and Study Area and Downstream. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) of the Upriver reach overlaps the Downtown reach; however, the medians do not overlap the spead. This, it is likely that the majority of the data points for the Upriver reach are greater than the Downtown reach. This is also observed between the Downtown and Study Area data sets where it is likely that the majority of the data points for the Study Area are greater than the Downtown reach. There is no overlap between the Downtown and Downstream spread; thus, the Downstream reach data set is greater than the Downtown data set. The spread and medians of the Upriver and Study Area reaches overlap each other; hence, there is no difference between these two data sets. This is also seen between the Upriver and Downstream data sets and the Study Area and Downstream data sets.

A box-whisker plot showing the relationship of dieldrin in sediment between the river reaches is presented in Figure 5.2-36. The relative dispersion of the Study Area data set is comparatively large. The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative dtata in the upper range of the data set. This is also seen to a lesser extent in the Downstream data set. The Downtown data set exhibits upward skewness while the Upriver and Downstream data sets exhibit downward skewness. It should be noted that the number of elevated detection limits in the Study Area reach will have an effect of skewing the data upward causing the comparisons of other data sets to this one less reliable.

Comparing the dieldrin data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downtown and Downstream data sets, followed by the Downtown and Study Area, Upriver and Downtown, Upriver and Study Area, Upriver and Downstream, and Study Area and Downstream. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of the Upriver and Downtown reaches overlap each other; hence, there is no difference between these two data sets. This is also seen between the Upriver and Downtown data sets, the Upriver and downstream data sets, and the Study Area and Downstream data sets. There is no overlap between the Downtown and Downstream spread; thus, the Downstream reach data set is greater than the Downtown data set.

Subsurface Sediment

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The upriver subsurface data set for both aldrin and dieldrin is comprised of only three nondetected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like surface sediment, the Study Area reach has far more data points (1,172 for aldrin and 1,208 for dieldrin) than the other reaches (Downtown – 94, Downstream – 26) which may have an effect on the comparison of the data sets.

The Study Area reach had the highest median of aldrin at 0.88 J ug/kg (Table 5.2-2), followed by the Downstream reach median of 0.49 J ug/kg (Table 5.2-20), and Downtown reach median of 0.21 J ug/kg (Table 5.2-16a). These tables also show that the means of the data sets follow the same order of reaches: Study Area reach (23 ug/kg), Downstream reach (1.2 ug/kg), and Downtown reach (0.41 ug/kg).

The Downtown reach had the highest median of dieldrin at 6 J ug/kg (Table 5.2-16a) followed by the Study Area reach median of 0.43 ug/kg (Tables 5.2-2); there are no detected values in the Downstream reach (Table 5.2-19). These tables show a similar pattern with the means: Downtown reach (7 ug/kg), and Study Area reach (3.6 ug/kg).

A box-whisker plot showing the relationship of aldrin in sediment between the river reaches is presented in Figure 5.2-32. The box-whisker plots use both detect and nondetect data. The whiskers on the low end are indicative of the lower detection limits for the data set. The relative dispersion of the Study Area data set is comparatively large. The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative dtata in the upper range of the data set. This is also seen to a lesser extent in the Downstream data set. The Downstream data sets exhibit downward skewness. It should be noted that the number of elevated detection limits in the Study Area reach will have an effect of skewing the data upward causing the comparisons of other data sets to this one less reliable.

Comparing the aldrin data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downtown and Downstream data sets, followed by the Downtown and Study Area, and Study Area and Downstream. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of the Downtown and Study Area reaches overlap each other; hence there is no difference between these two data sets. There is no overlap between the Downtown and Downstream spread; thus, the Downstream reach data set is greater than the Downtown data set. The spread of the Study Area and Downstream reaches overlap each other; however, the medians do not overlap the spead. This, it is likely that the majority of the data points for the Study Area reach are greater than the Downstream reach.

A box-whisker plot showing the relationship of dieldrin in sediment between the river reaches is presented in Figure 5.2-36. The relative dispersion of the Study Area data set is comparatively large. The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative dtata in the upper range of the data set. This is also seen to a lesser extent in the Downstream data set. The Downtown data set exhibits upward skewness while the Upriver and Downstream data sets exhibit downward skewness. It should be noted that the number of elevated detection limits in the Study Area reach will have an effect of skewing the data upward causing the comparisons of other data sets to this one less reliable.

Comparing the dieldrin data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downtown and Downstream data sets, followed by the Downtown and Study Area, and Study Area and Downstream. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

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Similar to the aldrin data set, the spread and medians of the Downtown and Study Area reaches overlap each other; hence there is no difference between these two data sets. There is no overlap between the Downtown and Downstream spread; thus, the Downstream reach data set is greater than the Downtown data set. The spread of the Study Area and Downstream reaches overlap each other; however, the medians do not overlap the spead. This, it is likely that the majority of the data points for the Study Area reach are greater than the Downstream reach.

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~~5.13.20.11~~5.2.9 Arsenic in Sediment

Several data presentations for the surface and subsurface arsenic data set within the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. The distribution of arsenic concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-25; concentrations with depth at subsurface stations are depicted on Maps 5.2-26a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-37 and 5.2-38 present scatter plots of the arsenic data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for arsenic in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respecteively. Tables 5.2-9 and 5.2-10 present arsenic data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-39.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-45. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-2-; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-40.

5.2.9.1 Arsenic Data Set

The Study Area data set of arsenic concentrations includes 1,551 surface samples and 1,553 subsurface samples. The Upriver data set includes 77 surface samples and 3 subsurface samples. The downtown data set includes 233 surface samples and 178 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples.

5.2.9.2 Arsenic in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Arsenci was analyzed in 77 surface sediment samples and detected in 73 samples within the Upriver reach (detection frequency of 95 percent), with detected concentrations ranging from 1.9 J mg/kg to 5.3 mg/kg (Table 5.2-11). Table 5.2-13 shows that all the detected data points are less than 10 mg/kg. The mean arsenic concentration in this reach is 2.9 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Arsenic was analyzed in 233 surface sediment samples and detected in 201 samples within the Downtown reach (detection frequency of 86 percent), with detected concentrations ranging from 1.1 mg/kg to 126 J mg/kg (Table 5.2-15a) and a mean concentration of 6.2 mg/kg. The arsenic concentrations in surface sediment varied along the Downtown reach (Map 5.2-45). The map shows that the majority of the samples are less than 5 mg/kg in this reach and that there are clusters of samples with concentrations greater than 25 mg/kg at RM 13 on the eastern shore under the Hawthorn Bridge and on the western shore between the Marquam and Ross Island bridges.

Table 5.2-17 shows that there is one sample greater than 100 mg/kg and 17 samples ranging between 10 and 100 mg/kg. The majority of the data, 183 samples or 91 percent of the detected data set, is detected at concentrations less than 10 mg/kg. There are no samples detected at concentrations less than 1 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Arsenic was analyzed in 74 surface sediment samples within the Zidell action area with concentrations ranging from 1.3 mg/kg to 78 J mg/kg (Table 5.2-15c). The mean arsenic concentration for this area is 11.2 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15b), the range of arsenic concentrations in surface sediment is from 1.1 mg/kg to 126 mg/kg with a mean concentration of 4.7 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Arsenic was analyzed in 1,551 surface sediment samples and detected in 1,426 samples within the Study Area (detection frequency of 92 percent) with concentrations ranging from 0.7 mg/kg to 132 mg/kg (Table 5.2-1). The mean arsenic concentration of surface sediment in the Study Area is 4.5 mg/kg. Arsenic concentrations in surface sediment varied along the Study Area (Figure 5.2-37).

Three prominent peaks (greater than or approaching 100 mg/kg) in the surface sediment are identified in the eastern nearshore zone (Figure 5.2-37). Clusters of concentrations greater than 10 mg/kg occur at RM 5.5, RM 7, and in Swan Island Lagoon (Figure 5.2-37 and Map 5.2-25). A single exceedance of 132 mg/kg is noted at RM 2.2. The highest surface concentration detected in the eastern nearshore zone (132 mg/kg) was found at Station RB08 at RM 2.2. Another sample detected at a concentration greater than 100 mg/kg is located at RM 5.6. Mean arsenic concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 5.76 mg/kg for RM 1.9 to 3; 7.05 mg/kg for RM 5 to 6; 7.16 mg/kg for RM 7 to 8; and 5.87 mg/kg in Swan Island Lagoon.

The western nearshore zone has detected arsenic concentrations that exceed 10 mg/kg from RM 3.5 through 7, RM 8.3 to 9.2, and at RM 10.2. It appears that three prominent peaks (concentrations approaching 100 mg/kg) are located at RM 6.8, RM 8.6, and RM 10.2 (Figure 5.2-37), but the remainder of the elevated concentrations appear to be more dispersed. The maximum surface concentration (80 mg/kg) was found at Station A2GS10 (RM 8.6W). Mean concentrations (Table 5.2-7) for this area in the western nearshore zone are: 4.86 mg/kg for RM 3 to 4; 4.10 mg/kg for RM 4 to 5; 4.12 mg/kg for RM 5 to 6; 5.99 mg/kg for RM 6 to 7; 9.17 mg/kg for RM 8 to 9; 5.79 mg/kg for RM 9 to 10; and 9.96 mg/kg for RM 10 to 11. There were no surface sediment samples detected in the navigation channel exceeding 10 mg/kg.

Table 5.2-9 shows that there are two detected data points in surface sediment greater than 100 mg/kg and there are 57 detected values between 10 and 100 mg/kg. Surface sediment values greater than 10 mg/kg accounts for four percent of the detected data set. The majority of the detected data set (1,364 samples; 96 percent of the detected data set) were detected at concentrations between 1 and 10 mg/kg. Only three samples were detected at concentrations less than 1 mg/kg.

Downstream Reach (RM 0 to 1.9)

Arsenic was analyzed and detected in 25 surface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 0.6 J mg/kg to 6.4 mg/kg (Table 5.2-19). Table 5.2-21 shows that the majority of the detected data set, 24 samples, is at concentrations between 1 and 10 mg/kg. Only one sample was detected at concentrations less than 1 mg/kg. The mean arsenic concentration in this reach is 3.7 mg/kg.

5.2.9.3 Arsenic in Subsurface Sediment

Upriver Reach (RM 15.3 to 26)

Arsenic concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 2.4 mg/kg to 2.5 mg/kg; the average concentration for this reach is 2.4 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Arsenic was analyzed in 178 subsurface sediment samples and detected in 168 samples within the Downtown reach (detection frequesncy of 94 percent), with concentrations ranging from 0.57 mg/kg to 7.5 mg/kg (Table 5.2-16a) and a mean concentration of 3.0 mg/kg. Table 5.2-17 shows that the majority of the data set (165 samples) is detected at concentrations between 1 and 10 mg/kg. The remaining data set (3 samples) were detected at concentrations less than 1 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the Downtown data set. Arsenic was analyzed in 30 subsurface sediment samples within the Zidell action area with concentrations ranging from 2 mg/kg to 7.5 mg/kg. The mean arsenic concentration for this area is 3.5 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-16c), the range of arsenic concentrations in subsurface sediment is from 0.57 mg/kg to 7.18 mg/kg with a mean concentration of 2.9 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Of the 1,553 subsurface samples analyzed for arsenic, 1,489 were detected (96 percent detection frequency) with concentrations ranging from an estimated 0.5 J mg/kg to 51 mg/kg (Table 5.2-2) and a mean concentration of 4.1 mg/kg. Similar to surface sediment, arsenic concentrations in the subsurface also varied within the Study Area (Figure 5.2-38; Maps 5.2-26a-o).

The subsurface sediment has a very different pattern than identified in the surface sediment within the eastern nearshore zone (Figure 5.2-26). Concentrations greater than 10 mg/kg are noted from RM 3.6 through RM 8.6 and in Swan Island Lagoon. Clusters of concentrations greater than 10 mg/kg occur at RM 3.6, RM 4.6, RM 5.6, RM 8.5, RM 11.3 and in Swan Island Lagoon (Figure 5.2-38 and Map 5.2-26a-o). Single points are noted at RM 6.7 and RM 7.4. The highest subsurface concentration (51 mg/kg) was found in the interval of 150–236 cm bml at Station C708 near the mouth of Swan Island Lagoon. Mean arsenic concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 3.61 mg/kg for RM 3 to 4; 3.47 mg/kg for RM 4 to 5; 5.37 mg/kg for RM 5 to 6; 4.11 mg/kg for RM 6 to 7; 4.11 mg/kg for RM 7 to 8; 11.8 mg/kg for RM 8 to 9; 4.81 mg/kg in Swan Island Lagoon; and 4.73 mg/kg for RM 11 to 11.8.

The western nearshore zone has detected arsenic concentrations that exceed 10 mg/kg from RM 3.6 through 9.2. It appears that there may be a prominent peak from RM 8.5 to 9.2 (Figure 5.2-38), but the remainder of the elevated concentrations appear to be more dispersed. A sample collected at RM 9.0 contained the highest subsurface concentration of arsenic (43.3 mg/kg) in the western nearshore zone of the Study Area (Station HA-38). Mean concentrations (Table 5.2-8) for this area in the western nearshore zone are: 6.07 mg/kg for RM 3 to 4; 4.04 mg/kg for RM 4 to 5; 4.25 mg/kg for RM 5 to 6; 3.61 mg/kg for RM 6 to 7; 4.34 mg/kg for RM 7 to 8; 5.67 mg/kg for RM 8 to 9; and 8.11 mg/kg for RM 9 to 10.

There are three samples greater than 10 m~~u~~g/kg in the navigation channel zone located at RM 7.9, 10.3 and 11.5. There is no discernable pattern with the concentrations elevated within the navigation channel. The mean concentrations for these areas are: 4.18 mg/kg for RM 7 to 8; 4.02 mg/kg for RM 10 to 11, and 3.03 mg/kg for RM 11 to 11.8 (Table 5.2-6).

Table 5.2-9 shows that there are 45 subsurface samples (3 percent of the detected data set) greater than 10 mg/kg. The majority of the detected data set (1,433 samples; 96 percent) is between 1 and 10 mg/kg. The remaining 11 data points (<1 percent) is comprised of concentrations less than 1 mg/kg.

Downstream Reach (RM 0 to 1.9)

Arsenic was analyzed and detected in 26 subsurface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 0.6 J mg/kg to 13 mg/kg (Table 5.2-20). Table 5.2-21 shows that there is one sample detected at a concentration greater than 10 mg/kg. The majority of the samples (24 samples; 92 percent) were detected at concentrations between 1 and 10 mg/kg. Only one sample was detected at a concentration less than 1 mg/kg. The mean arsenic concentration in this reach is 4.1 mg/kg.

5.2.9.4 Arsenic Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean arsenic surface sediment concentration in this reach is 2.9 mg/kg (Table 5.2-11).

The surface sediment concentrations in the downtown reach were greater than the subsurface concentrations, indicating that there may be ongoing sources in this reach. The mean surface concentration is 6.2 mg/kg, while the mean subsurface sediment concentration is 3.0 mg/kg (Tables 5.2-15a and 5.2-16a).

Arsenic concentrations are also generally greater in the surface sediments than in subsurface sediments within the Study Area as a whole. The mean surface sediment concentration is 4.5 mg/kg and the mean subsurface sediment concentration is 4.1 mg/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-39 shows that mean concentrations are greater in the nearshore areas than in the navigation channel and the western nearshore zone is slightly greater than the eastern nearshore zone. It also shows that concentrations are generally greater in the surface sediment than in subsurface sediment.

In the eastern nearshore zone, surface sediment is greater than subsurface sediment in all river mile zones except RM 8 to 9 and RM 11 to 11.8. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles excpt RM 4 to 5, RM 6 to 7, RM 8 to 9, and possibly RM 10 to 11. The subsurface sediment concentrations in the navigation channel are generally the same as the surface sediment concentrations.

Areas where subsurface sediment concentrations are elevated do not align with the locations where surface sediment concentrations are elevated. The most prominent areas are RM 8 to 9 in the eastern nearshore zone, and RM 8 to 9 and RM 10 to 11 in the western nearshore zones. Additional areas with elevated concentrations are RM 1.9 to 3, RM 5 to 6, RM 7 to 8, and Swan Island lagoon in the eastern nearshore zone, and RM 3 to 4, RM 6 to 7, and RM 8 to 10 in the western nearshore zone (Figure 5.2-39).

The surface sediment concentrations in the downstream reach were greater than subsurface concentrations. The mean surface concentration is 4.1 mg/kg, while the mean subsurface concentration is 3.8 mg/kg (Tables 5.2-19 and 5.2-20)

5.2.9.5 Arsenic Sediment Relationship by River Reach

Comparisons of the arsenic data sets between the river reaches (Upriver, Downtown, Study Area, and Downstream) are discussed using the summary statistics and box-whisker plots.

Surface Sediment

There were far more data points in the Study Area reach (1,551) than in the other river reaches (Upriver – 77; Downtown – 233; Downtown excluding Zidell – 159; and Downstream – 25) which may affect the comparability of the data sets.

The, Downstream reach has the highest median of 4.1 mg/kg (Table 5.2-19) followed by the Study Area reach median of 3.7 J mg/kg (Table 5.2-1), the Downtown reach meadian of 3.1 mg/kg (Table 5.2-15a), the Downtown reach excluding Zidell median of 2.9 mg/kg (Table 5.2-15b), and the Upriver reach median of 2.8 mg/kg (Table 5.2-11). These tables also show that the means of the data sets result in a slightly different order of the reaches: Downtown reach (6.2 mg/kg); Downtown excluding Zidell (4.7 mg/kg); Study Area reach (4.5 mg/kg), Downstream reach (3.7 mg/kg); and Upriver reach (2.9 mg/kg).

A box-whisker plot showing the relationship of arsenic in sediment between the river reaches is presented in Figure 5.2-40. The box-whisker plots were plotted using both detet and nondetect data. The whiskers on the low end are indicative of the detection limits.

The relative dispersion of the Upriver data set, and to some extent the Downstream data set, is comparatively small. The length of the inner quartile for the Study Area and Downtown reaches are small compared to the whiskers, sugguestion a middle clustering of data about the median with a long upper whisker, representing a large dispersion of the relative data in the upper range of the data set. This is also seen to a lesser extent in the Downtown data set where there is a long lower whisker. The Downstream data set exhibits upward skewness while the Study Area and Downtown data sets exhibit downward skewness.

Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap in the Upriver and Study Area data sets, followed by the Upriver and Downstream, Downtown and Study Area, Downtown and Downstream, Study Area and Downstream, and Upriver and Downtown. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and median of the Upriver reach overlaps with the spread and median of the Downtown data set; hence, there is no difference between these two data sets. Likewise, the spread and median of the Study Area and Downstream reaches and Study Area and Downstream reaches overlap so there is no difference between those data sets. The spead of the Upriver reach overlaps the spread of the Study Area reach and Downstream reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Study Area and Downstream are greater than the data points collected Upriver. This is also observed between the Downtown reach and the Study Area reach indicating that the majority of the data in the Study Area reach is greater than the data points collected in the Downtown reach and between the Downtown reach and the Downstream reach indicating that the majority of the data in the Downstream reach is greater than the data points collected in the Downtown reach.

Subsurface Sediment

The Upriver subsurface data set is comprised of only three nondetected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like the surface sediment, the Study Area reach has far more data points (1,553) than the other reaches (Downtown – 178; Downtown excluding Zidell – 148; and Downstream – 26) which may have an effect on the comparison of the data sets.

The Downstream reach has the highest median of 3.8 mg/kg (Table 5.2-20), followed by the Study Area reach median of 3.6 mg/kg (Table 5.2-2), the Downtown reach median of 2.9 mg/kg (Table 5.2-16a) and the Downtown reach excluding Zidell median of 2.7 mg/kg (Table 5.2-16b). These tables also show the means of the data set result in a different order of reaches: Study Area reach and Downstream reach (4.1 mg/kg), Downtown reach (3.0 mg/kg), and Downtown reach excluding Zidell (2.9 mg/kg).

A box-whisker plot (Figure 5.2-40) showing the relationship of arsenic in sediment between the river reaches were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the Downstream data set is comparatively small. The length of the inner quartile for the Study Area reach is small compared to the whiskers, suggesting a middle clustering of data about the median. The long upper whisker of the Study Area reach represents a large dispersion of the relative data in the upper range of the data set. The Downtown data set exhibits this to a lesser extent. The Downtown and Downstream data sets exhibit downward skewness while the Study Area data set exhibits upward skewness.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downtown and Study Area data sets, followed by the Downstream and Study Area data sets, and the Downtown and Downstream data sets. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of the Downtown reach and the Downstream reach overlap each other; hence there is no difference between these data sets. This is also observed between the Study Area and Downstream data sets. The spead of the Downtown reach overlaps the spread of the Study Area reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Study Area are greater than the data points collected in the Downtown reach.

~~5.13.20.12~~5.2.10 Chromium in Sediment

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Several data presentations for the surface and subsurface chromium data set within the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. The distribution of chromium concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-27; concentrations with depth at subsurface stations are depicted on Maps 5.2-28a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-41 and 5.2-42 present scatter plots of the chromium data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for chromium in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respecteively. Tables 5.2-9 and 5.2-10 present chromium data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-43.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the

Downtown reach surface sediment samples are presented in Map 5.2-46. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-44.

5.2.10.1 Chromium Data Set

The Study Area data set of chromium concentrations includes 1,536 surface samples and 1,530 subsurface samples. The Upriver data set includes 66 surface samples and 3 subsurface samples. The downtown data set includes 265 surface samples and 178 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples.

5.2.10.2 Chromium in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Chromium was analyzed and detected in 66 surface sediment samples within the Upriver reach (detection frequency of 100 percent), with detected concentrations ranging from 12 J mg/kg to 41 mg/kg (Table 5.2-11). Table 5.2-13 shows that all the detected data points are between 10 and 100 mg/kg. The mean chromium concentration in this reach is 23 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Chromium was analyzed and detected in 265 surface sediment samples within the Downtown reach (detection frequency of 100 percent), with detected concentrations ranging from 1.2 J mg/kg to 758 J mg/kg (Table 5.2-15a) and a mean concentration of 35 mg/kg. The chromium concentrations in surface sediment varied along the Downtown reach (Map 5.2-46). The map shows that the majority of the samples are less than 50 mg/kg in this reach and that there are clusters of samples with concentrations greater than 50 mg/kg at RM 13 on the eastern shore under the Hawthorn Bridge and on the western shore between the Marquam and Ross Island bridges.

Table 5.2-17 and 5.2-18 shows that there are 14 samples (5 percent of data set) greater than 100 mg/kg. The majority of the data, 218 samples or 82 percent of the data set, is detected at concentrations ranging between 10 and 100 mg/kg. The remaining 33 samples (12 percent of data set) are at concentrations less than 10 mg/kg. There are no samples detected at concentrations less than 1 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Chromium was analyzed in 110 surface sediment samples within the Zidell action area with concentrations ranging from 1.24 J mg/kg to 758 J mg/kg (Table 5.2-15c). The mean chromium concentration for this area is 56 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15b), the range of chromium concentrations in surface sediment is from 4.5 mg/kg to 189 mg/kg with a mean concentration of 19 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Chromium was analyzed in 1,536 surface sediment samples and detected in 1,530 samples within the Study Area (detection frequency of 99.6 percent) with concentrations ranging from 4.1 J mg/kg to 819 J mg/kg (Table 5.2-1). The mean chromium concentration of surface sediment in the Study Area is 35 mg/kg. Chromium concentrations in surface sediment varied along the Study Area (Figure 5.2-41).

Four prominent peaks (greater than 100 mg/kg) in the surface sediment are identified in the eastern nearshore zone (Figure 5.2-41). Clusters of concentrations greater than 100 mg/kg occur at RM 2.1-2.4, RM 3.7-4.4, RM 5.6-5.9, and in Swan Island Lagoon (Figure 5.2-41 and Map 5.2-27). A single exceedance of concentrations greater than 100 mg/kg is noted at RM 7.2 and RM 11. The highest surface concentration detected in the eastern nearshore zone (819 J mg/kg) was found at Station RB06 at RM 2.2. Mean chromium concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 100 mg/kg for RM 1.9 to 3; 31 mg/kg for RM 3 to 4; 29 for RM 4 to 5; 45 mg/kg for RM 5 to 6; 35 mg/kg for RM 7 to 8; 35 mg/kg in Swan Island Lagoon; and 38 mg/kg for RM 11 to 11.8.

The western nearshore zone has detected chromium concentrations that exceed 100 mg/kg from RM 6 through 9.2. It appears that three prominent peaks (concentrations greater than 100 mg/kg) are located at RM 6-6.1, RM 6.8-6.9, and RM 8.8-9.2 (Figure 5.2-41), but the remainder of the elevated concentrations appear to be more dispersed. The maximum surface concentration (774 mg/kg) was found at Station 19A01 (RM 8.4W). Mean concentrations (Table 5.2-7) for this area in the western nearshore zone are: 39 mg/kg for RM 6 to 7; 35 mg/kg for RM 7 to 8; 47 mg/kg for RM 8 to 9; and 39 mg/kg for RM 9 to 10. There were no surface sediment samples detected in the navigation channel exceeding 100 mg/kg.

Table 5.2-9 shows that there are 39 detected data points (three percent of the detected data set) in surface sediment greater than 100 mg/kg. The majority of the detected data set (1,466 samples; 96 percent of the detected data set) were detected at concentrations between 10 and 100 mg/kg. The remaining 25 surface sediment samples were detected at concentrations less than 10 mg/kg. There were no samples were detected at concentrations less than 1 mg/kg.

~~Chromium concentrations were relatively low (<50 mg/kg) throughout the majority of the Study Area (Maps 5.1-21 and 5.1-22a–m, see frequency plot inset), including the navigation channel. Detection frequencies were nearly 100 percent for both surface and subsurface samples (Tables 5.1-1 and 5.1-2). Ninety-five percent of the surface samples were below 55.8 V mg/kg.~~

~~Clusters of chromium concentrations greater than 50 mg/kg were identified in several areas along the eastern and western shorelines (Maps 5.1-21 and 5.1-22a–m; Figures 5.1-25 and 5.1-26). The maximum chromium surface concentration was found at Station RB06 in the RM 2.2 vicinity.~~

Downstream Reach (RM 0 to 1.9)

Chromium was analyzed and detected in 25 surface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 10 J mg/kg to 42 mg/kg (Table 5.2-19). Table 5.2-21 shows that the entire data set, 25~~4~~ samples, is at concentrations between 10 and 100 mg/kg. The mean chromium concentration in this reach is 25 mg/kg.

5.2.10.3 Chromium in Subsurface Sediment

Upriver Reach (RM 15.3 to 26)

Chromium concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 20 mg/kg to 23 mg/kg; the average concentration for this reach is 21 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Chromium was analyzed in 178 subsurface sediment samples and detected in 174 samples within the Downtown reach (detection frequesncy of 98 percent), with concentrations ranging from 4.6 mg/kg to 143 mg/kg (Table 5.2-16a) and a mean concentration of 22 mg/kg. Table 5.2-17 shows that only one sample was detected at a concentration greater than 100 mg/kg. The majority of the data set (161 samples; 93 percent of the detected data set) is detected at concentrations between 1 and 10 mg/kg. The remaining data set (12 samples) were detected at concentrations less than 1 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the Downtown data set. Chromium was analyzed in 30 subsurface sediment samples within the Zidell action area with concentrations ranging from 14 mg/kg to 143 mg/kg. The mean chromium concentration for this area is 36 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-16c), the range of chromium concentrations in subsurface sediment is from 4.6 mg/kg to 72 mg/kg with a mean concentration of 19 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Of the 1,530 subsurface samples analyzed for chromium, 1,524 were detected (99.6 percent detection frequency) with concentrations ranging from an estimated 6.4 J mg/kg to 484 mg/kg (Table 5.2-2) and a mean concentration of 29 mg/kg. Similar to surface sediment, chromium concentrations in the subsurface also varied within the Study Area (Figure 5.2-42; Maps 5.2-28a-o).

The subsurface sediment has elevated concentrations in areas identified in the surface sediment within the eastern nearshore zone (Figure 5.2-26). Concentrations greater than 100 mg/kg are noted at RM 2.2-2.4, RM 5.6 and in Swan Island Lagoon (Figure 5.2-42 and Map 5.2-28a-o). The highest subsurface concentration in the eastern nearshore zone (249 mg/kg) was found at Station C207-1 near RM 5.6. Mean chromium concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 30.5 mg/kg for RM 1.9 to 3; 56 mg/kg for RM 5 to 6; and 31 mg/kg in Swan Island Lagoon.

The western nearshore zone has detected chromium concentrations that exceed 100 mg/kg at RM 6.1, RM 7.4 and RM 8.8-9.2 (Figure 5.2-38). The maximum subsurface concentration (484 mg/kg) was found at Station HA-42 (46–61 cm bml) at RM 8.9. Mean concentrations (Table 5.2-8) for these areas in the western nearshore zone are: 30.3 mg/kg for RM 6 to 7; 32.3 mg/kg for RM 7 to 8; 35.2 mg/kg for RM 8 to 9; and 60.5 mg/kg for RM 9 to 10.

There are two samples greater than 100 mg/kg in the navigation channel zone located at RM 6.4 and 11.3. There is no discernable pattern with the concentrations elevated within the navigation channel although the sample at RM 6.4 is near the western nearshore zone and the sample at RM 11.3 is near the eastern nearshore zone. The mean concentrations for these areas are: 22.9 mg/kg for RM 6 to 7; and 21.5 mg/kg for RM 11 to 11.8 (Table 5.2-6).

Table 5.2-9 shows that there are 14 subsurface samples (<1 percent of the detected data set) greater than 100 mg/kg. The majority of the detected data set (1,452 samples; 95 percent) is between 10 and 100 mg/kg. The remaining 58 data points (4 percent) is comprised of concentrations less than 10 mg/kg. There were no samples detected at concentrations less than 1 mg/kg.

Downstream Reach (RM 0 to 1.9)

Chromium was analyzed and detected in 26 subsurface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 6.6 mg/kg to 34 mg/kg (Table 5.2-20). Table 5.2-21 shows that the majority of samples (25 samples) were detected at a concentration greater than 10 mg/kg. Only one sample was detected at a concentration less than 10 mg/kg and no samples were detected at concentrations less than 1 mg/kg. The mean chromium concentration in this reach is 23 mg/kg.

5.2.10.4 Chromium Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean chromium surface sediment concentration in this reach is 23 mg/kg (Table 5.2-11).

The surface sediment concentrations in the downtown reach were greater than the subsurface concentrations, indicating that there may be ongoing sources in this reach. The mean surface concentration is 35 mg/kg, while the mean subsurface sediment concentration is 22 mg/kg (Tables 5.2-15a and 5.2-16a).

Chromium concentrations are also generally greater in the surface sediments than in subsurface sediments within the Study Area as a whole. The mean surface sediment concentration is 35 mg/kg and the mean subsurface sediment concentration is 29 mg/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-43 shows that mean concentrations are greater in the nearshore areas than in the navigation channel and the western nearshore zone has slightly greater subsurface concentrations than the eastern nearshore zone while the eastern nearshore zone has higher surface concentration. It also shows that concentrations are generally about the same in the surface sediment and subsurface sediment.

In the eastern nearshore zone, surface sediment is greater than subsurface sediment in all river mile zones except RM 5 to 7 and RM 8 to 9. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles excpt RM 9 to 10 and RM 11 to 11.8. The subsurface sediment concentrations in the navigation channel are generally the same as the surface sediment concentrations, although the surface sediment concentrations are slightly greater in all river miles except RM 6 to 7, RM 8 to 9, and RM 9 to 10.

Areas where subsurface sediment concentrations are elevated align with the locations where surface sediment concentrations are elevated, although there are more areas with elevated surface sediment concentrations. The most prominent areas are RM 1.9 to 3 and RM 5 to 6 in the eastern nearshore zone, and RM 8 to 10 in the western nearshore zones. Additional areas with elevated concentrations are RM 11 to 11.8 in the eastern nearshore zone, and RM 6 to 7 in the western nearshore zone (Figure 5.2-39).

The surface sediment concentrations in the downstream reach were greater than subsurface concentrations. The mean surface concentration is 25 mg/kg, while the mean subsurface concentration is 23 mg/kg (Tables 5.2-19 and 5.2-20)

5.2.10.5 Chromium Sediment Relationship by River Reach

Comparisons of the chromium data sets between the river reaches (Upriver, Downtown, Study Area, and Downstream) are discussed using the summary statistics and box-whisker plots.

Surface Sediment

There were far more data points in the Study Area reach (1,536) than in the other river reaches (Upriver – 66; Downtown – 265; Downtown excluding Zidell – 155; and Downstream – 25) which may affect the comparability of the data sets.

The, Study Area reach has the highest median of 29 mg/kg (Table 5.2-1) followed by the Downstream reach median of 27 mg/kg (Table 5.2-19), the Upriver reach meadian of 23 J mg/kg (Table 5.2-11), the Downtown reach median of 21 J mg/kg (Table 5.2-15a); and the Downtown reach excluding Zidell median of 17 mg/kg (Table 5.2-15b). These tables also show that the means of the data sets result in a slightly different order of the reaches: Downtown reach (35 mg/kg); Study Area reach (35 mg/kg); Downstream reach (25 mg/kg); Upriver reach (23 mg/kg); and Downtown reach excluding Zidell (19 mg/kg).

A box-whisker plot showing the relationship of chromium in sediment between the river reaches is presented in Figure 5.2-44. The box-whisker plots were plotted using both detet and nondetect data. The whiskers on the low end are indicative of the detection limits.

The relative dispersion of the Upriver data set and the Downstream data set are comparatively small. The length of the inner quartile for the Study Area and Downtown reaches are small compared to the whiskers, sugguestion a middle clustering of data about the median with a long upper whisker, representing a large dispersion of the relative data in the upper range of the data set. The Downstream and Dowdown excluding Zidell data sets exhibit upward skewness.

Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap in the Downtown exluding Zidell and Study Area data sets, followed by the Upriver and Study Area, Downstream and Study Area, Downtown excluding Zidell and Downstream, Upriver and Downtown excluding Zidell, Study Area and Downtown, Downtown excluding Zidell and Downtown, Downtown and Downstream, Upriver and Downtown, and Upriver and Downstream. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and median of the Upriver reach overlaps with the spread and median of the Downtown data set; hence, there is no difference between these two data sets. Likewise, the spread and median of the Upriver and Downstream reaches Downtown excluding Zidell and Downstream reaches, and Downtown and Downstream reaches overlap so there is no difference between those data sets. The spead of the Upriver reach overlaps the spread of the Downtown excluding Zidell reach and Study Area reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Study Area and Downstream are greater than the data points collected Upriver. This is observed between the Downtown excluding Zidell reach and the Downstream reach indicating that the majority of the data in the Downstream reach is greater than the data points collected in the Downtown reach excluding Zidell. Additional similar observation between the Study Area and the Downtown reach and Downstream reach indicating the Study Area reach is greater than the data points collected in the Downtown excluding Zidell reach and Downstream reach. The spread and median of the Downtown excluding Zidell reach and Study Area reach do not overlap indicating that the majority of the data in the Study Area reach is greater than the data points collected in the Downtown excluding Zidell reach.

Subsurface Sediment

The Upriver subsurface data set is comprised of only three nondetected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like the surface sediment, the Study Area reach has far more data points (1,530) than the other reaches (Downtown – 178; Downtown excluding Zidell – 148; and Downstream – 26) which may have an effect on the comparison of the data sets.

The Study Area reach has the highest median of 27 J mg/kg (Table 5.2-2), followed by the Downstream reach median of 25 mg/kg (Table 5.2-20), the Downtown reach median of 20 mg/kg (Table 5.2-16a) and the Downtown reach excluding Zidell median of 19 mg/kg (Table 5.2-16b). These tables also show the means of the data set result in the same order of reaches: Study Area reach (29 mg/kg) and Downstream reach (23 mg/kg), Downtown reach (22 mg/kg), and Downtown reach excluding Zidell (19 mg/kg).

A box-whisker plot (Figure 5.2-44~~0~~) showing the relationship of ~~arsenic~~chromium in sediment between the river reaches were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the Downstream data set is comparatively small. The length of the inner quartile for the Study Area and Downtown reaches is small compared to the whiskers, suggesting a middle clustering of data about the median. The long upper whisker of the Study Area reach represents a large dispersion of the relative data in the upper range of the data set. The Downtown excluding Zidell data set exhibits this to a lesser extent. The Downtown excluding Zidell and Downstream data sets exhibits ~~downward~~upward skewness~~ while the Study Area data set exhibits upward skewness~~.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downtown excluding Zidell and ~~Downstream~~Study Area data sets, followed by the Downtown~~stream~~ and Study Area data sets, ~~and~~ the Downtown and ~~Study Area~~Downstream data sets, the Downtown excluding Zidell and Downstream data sets, the Study Area and Downstream data sets, and the Downtown exceluding Zidell and

Downtown data sets. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of the Downtown reach and the ~~Study Area~~Downtown~~stream~~ reach excluding Zidell overlap each other; hence there is no difference between these data sets. This is also observed between the Study Area and Downstream data sets. The spead of the Downtown reach overlaps the spread of the ~~Downstream~~Study Area reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the ~~Downstream~~Study Area are greater than the data points collected in the Downtown reach. This is also observed between the Study Area and Downtown data sets, the Study Area and Downtown excluding Zidell data sets, and the Downtwon and Downstream data sets.

~~5.13.20.14~~5.2.11 Copper in Sediment

Several data presentations for the surface and subsurface copper data set within the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. The distribution of copper concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-29; concentrations with depth at subsurface stations are depicted on Maps 5.2-30a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-45 and 5.2-46 present scatter plots of the copper data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for copper in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respecteively. Tables 5.2-9 and 5.2-10 present copper data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-47.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-47. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in

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Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-48.

5.2.11.1 Copper Data Set

The Study Area data set of copper concentrations includes 1,552 surface samples and 1,541 subsurface samples. The Upriver data set includes 72 surface samples and 3 subsurface samples. The downtown data set includes 269 surface samples and 178 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples.

5.2.11.2 Copper in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Copper was analyzed and detected in 72 surface sediment samples within the Upriver reach (detection frequency of 100 percent), with detected concentrations ranging from 11 J mg/kg to 51 mg/kg (Table 5.2-11). Table 5.2-13 shows that all the detected data points are between 10 and 100 mg/kg. The mean copper concentration in this reach is 25 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Copper was analyzed in 269 surface sediment samples within the Downtown reach and detected in 264 samples (detection frequency of 98 percent), with detected concentrations ranging from 5.5 mg/kg to 2,150 J mg/kg (Table 5.2-15a) and a mean concentration of 99 mg/kg. The copper concentrations in surface sediment varied along the Downtown reach (Map 5.2-47). The map shows that the majority of the samples are less than 300 mg/kg in this reach and that there are clusters of samples with concentrations greater than 600 mg/kg at RM 13 on the western shore under the Hawthorn Bridge and on the western shore between the Marquam and Ross Island bridges.

Table 5.2-17 and 5.2-18 shows that there are 7 samples (3 percent of data set) greater than 1,000 mg/kg. Another 29 samples (11 percent of the data set, are detected at concentrations ranging from 100 to 1,000 mg/kg. The majority of the data, 222 samples or 84 percent of the data set, is detected at concentrations ranging between 10 and 100 mg/kg. The remaining 2 samples (12 percent of data set) are at concentrations less than 10 mg/kg. There are no samples detected at concentrations less than 1 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Copper was analyzed in 110 surface sediment samples within the Zidell action area with concentrations ranging from 5.51 mg/kg to 2,150 J mg/kg (Table 5.2-15c). The mean copper concentration for this area is 195 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15b), the range of copper concentrations in surface sediment is from 8.4 mg/kg to 366 mg/kg with a mean concentration of 33 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Copper was analyzed in 1,552 surface sediment samples and detected in 1,548 samples within the Study Area (detection frequency of 99.7 percent) with concentrations ranging from 6.2 J mg/kg to 2,830 mg/kg (Table 5.2-1). The mean copper concentration of surface sediment in the Study Area is 61 mg/kg. Copper concentrations in surface sediment varied along the Study Area (Figure 5.2-45).

Five prominent peaks (greater than 100 mg/kg) in the surface sediment are identified in the eastern nearshore zone (Figure 5.2-45). Clusters of concentrations greater than 100 mg/kg occur at RM 2.1-2.4, RM 3.7-4, RM 5.5-6.1, in Swan Island Lagoon, and RM 11.1-11.3 (Figure 5.2-45 and Map 5.2-29). A single exceedance of concentrations greater than 100 mg/kg is noted at RM 6.6, RM 7.2 and RM 9.9. ~~Copper data showed concentrations greater than 60 mg/kg (Maps 5.1-23 and 5.1-24a–m, see frequency plot inset) at many locations along the eastern and western nearshore zones, but few in the navigation channel. Detection frequencies were nearly 100 percent for both surface and subsurface samples (Figures 5.1-27 and 5.1-28; Tables 5.1-1 and 5.1-2). Ninety-five percent of the surface samples were below 172 V mg/kg.~~

~~As shown in Maps 5.1-23 and 5.1-24a–m, copper was greater than 60 mg/kg in isolated groupings at several locations along the eastern and western shorelines.~~ A surface sample at RM 11.2 (Station UG01) contained the highest concentration of copper (2,830 mg/kg). Mean copper concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 42 mg/kg for RM 1.9 to 3; 38 mg/kg for RM 3 to 4; 135 mg/kg for RM 5 to 6; 53.5 mg/kg for RM 6 to 7; 53 mg/kg for RM 7 to 8; 122 mg/kg in Swan Island Lagoon; 31.6 mg/kg for RM 9-10; and 161 mg/kg for RM 11 to 11.8.

The western nearshore zone has detected copper concentrations that exceed 100 mg/kg from RM 4.3 through 10.4. It appears that five prominent peaks (concentrations greater than 100 mg/kg) are located at RM 4.3-4.7, RM 5.6-6.1, RM 6.8-7.4, RM 8.3-9.2, and RM 10.2-10.4 (Figure 5.2-45), but the remainder of the elevated concentrations appear to be more dispersed. The maximum surface concentration in the western nearshore zone (1,370 mg/kg) was found at Station HA-43 (RM 9.2W). Mean concentrations (Table 5.2-7) for these areas in the western nearshore zone are: 39.8 mg/kg for RM 4 to

5; 50.7 mg/kg for RM 5 to 6; 46.9 mg/kg for RM 6 to 7; 41.4 mg/kg for RM 7 to 8; 102 mg/kg for RM 8 to 9; 110 mg/kg for RM 9 to 10; and 164 mg/kg for RM 10 to 11.

There were three prominent peaks in the navigation channel zone is located at RM 5, RM 7.9, and RM 10.3-10.4. The peaks at RM 5 and 7.9 appears to be associated with elevated concentrations in the eastern nearshore area while the peak at RM 10.3-10.4 appears to be associated with elevated concentrations in the western nearshore area (Map 5.2-29). The mean concentrations for these areas are: 30.1 mg/kg for RM 5 to 6; 49.3 mg/kg for RM 7 to 8; 62 mg/kg for Swan Island Lagoon; and 39.7 mg/kg for RM 10 to 11 (Table 5.2-5).

Table 5.2-9 shows that there are 4 samples exceeding 1,000 mg/kg. Another 144 detected data points in surface sediment greater than 100 mg/kg. Surface sediment values greater than 100 mg/kg accounts for ten percent of the detected data set. The majority of the detected data set (1,392 samples; 90 percent of the detected data set) were detected at concentrations between 10 and 100 mg/kg. The remaining eight surface sediment samples were detected at concentrations less than 10 mg/kg. There were no samples were detected at concentrations less than 1 mg/kg.

Downstream Reach (RM 0 to 1.9)

Copper was analyzed and detected in 25 surface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 8 mg/kg to 46 mg/kg (Table 5.2-19). Table 5.2-21 shows that 23 samples are measured at concentrations between 10 and 100 mg/kg and two samples are measured at concentration between 1 and 10 mg/kg. There were no samples were detected at concentrations less than 1 mg/kg. The mean copper concentration in this reach is 26 mg/kg.

5.2.11.3 Copper in Subsurface Sediment

Upriver Reach (RM 15.3 to 26)

Copper concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 26 mg/kg to 33 mg/kg; the average concentration for this reach is 29 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Copper was analyzed and detected in 178 subsurface sediment samples within the Downtown reach (detection frequesncy of 100 percent), with concentrations ranging from 9.5 mg/kg to 1,050 mg/kg (Table 5.2-16a) and a mean concentration of 46 mg/kg. Table 5.2-17 shows that only one sample was detected at a concentration greater than 1,000 mg/kg. Another eight samples were detected at concentrations between 100 and 1,000 mg/kg. Subsurface sediment values greater than 100 mg/kg account for five percent of the detected data set. The majority of the data set (167 samples; 94 percent of the detected data set) is detected at concentrations between 10 and 100 mg/kg. The remaining data set (2 samples) were detected at concentrations less than 10 mg/kg. There were no samples were detected at concentrations less than 1 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the Downtown data set. Copper was analyzed in 30 subsurface sediment samples within the Zidell action area with concentrations ranging from 14 mg/kg to 1,050 mg/kg. The mean copper concentration for this area is 42 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-16c), the range of copper concentrations in subsurface sediment is from 9.5 mg/kg to 457 mg/kg with a mean concentration of 39 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Of the 1,552 subsurface samples analyzed for copper, 1,548 were detected (99.7 percent detection frequency) with concentrations ranging from an estimated 9.4 J mg/kg to 3,290 mg/kg (Table 5.2-2) and a mean concentration of 55 mg/kg. Similar to surface sediment, copper concentrations in the subsurface also varied within the Study Area (Figure 5.2-46; Maps 5.2-30a-o).

The subsurface sediment has elevated concentrations in generally the same areeas identified in the surface sediment within the eastern nearshore zone (Figure 5.2-46). Concentrations greater than 100 mg/kg are noted at RM 3.6, RM 4.4-4.6, RM 5.6, RM 6.1-6.7, RM 7.4, in Swan Island Lagoon, RM 8.4-8.8, and RM 11.3 (Figure 5.2-46 and Map 5.2-30a-o). The maximum subsurface copper concentration (3,290 mg/kg) was found at Station C384 (30–128 cm bml), at the mouth of Swan Island Lagoon. Mean copper concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 35.6 mg/kg for RM 3 to 4; 30.2 mg/kg for RM 4 to 5; 56.9 mg/kg for RM 5 to 6; 70 mg/kg for RM 6 to 7; 48.3 mg/kg for RM 7 to 8; 128 mg/kg for RM 8 to 9; and 145 mg/kg in Swan Island Lagoon.

The western nearshore zone has detected copper concentrations that exceed 100 mg/kg from RM 4.1 through 9.2 with clusters noted at RM 4.8-4.9 and RM 8.3-9.2 (Figure 5.2-46 and Map 5.2-30a-o). The maximum subsurface concentration (1,990 mg/kg) was found at Station HA-42 (46–61 cm bml) at RM 8.9. Mean concentrations (Table 5.2-8) for these areas in the western nearshore zone are: 48 mg/kg for RM 4 to 5; 33.9 mg/kg for RM 5 to 6; 39.4 mg/kg for RM 6 to 7; 42.6 mg/kg for RM 7 to 8; 59.8 mg/kg for RM 8 to 9; and 229 mg/kg for RM 9 to 10.

There are two peaks with samples greater than 100 mg/kg in the navigation channel zone located at RM 7.6-8 and RM 10.2-10.3. The concentrations elevated within the navigation channel at RM 7.6-8 are near elevated concentrations in the eastern nearshore zone and the samples at RM 10.2-10.3 are near elevated concentrations the western nearshore zone. The mean concentrations for these areas are: 68.7 mg/kg for

RM 7 to 8; 88.2 mg/kg for Swan Island Lagoon; and 51.4 mg/kg for RM 10 to 11 (Table 5.2-6).

Table 5.2-9 shows that there are 6 subsurface samples greater than 1,000 mg/kg and 78 samples ranging between 100 and 1,000 mg/kg. Subsurface sediment values greater than 100 mg/kg accounts for five percent of the detected data set. The majority of the detected data set (1,456 samples; 94 percent) is between 10 and 100 mg/kg. The remaining data point is at a concentration less than 10 mg/kg. There were no samples detected at concentrations less than 1 mg/kg.

Downstream Reach (RM 0 to 1.9)

Copper was analyzed and detected in 26 subsurface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 8.9 mg/kg to 44 mg/kg (Table 5.2-20). Table 5.2-21 shows that the majority of samples (24 samples) were detected at a concentration greater than 10 mg/kg. Only two samples were detected at a concentration less than 10 mg/kg and no samples were detected at concentrations less than 1 mg/kg. The mean copper concentration in this reach is 26 mg/kg.

5.2.11.4 Copper Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean copper surface sediment concentration in this reach is 25 mg/kg (Table 5.2-11).

The surface sediment concentrations in the downtown reach were greater than the subsurface concentrations. The mean surface concentration is 99 mg/kg, while the mean subsurface sediment concentration is 46 mg/kg (Tables 5.2-15a). However, when the Zidell data is removed from the Downtown reach data set, the surface and subsurface sediment concentrations are approximately the same. The mean surface sediment concentration is 33 mg/kg and the mean subsurface sediment concentration is 39 mg/kg (Table 5.2-15b).

Copper concentrations are generally greater in the subsurface sediments than in surface sediments within the Study Area as a whole. The mean surface sediment concentration is 61 mg/kg and the mean subsurface sediment concentration is 55 mg/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-47 shows that mean concentrations are greater in the nearshore areas than in the navigation channel and the eastern nearshore zone has greater concentrations than the western nearshore zone. It also shows that concentrations are generally about the same in the surface sediment and subsurface sediment.

In the eastern nearshore zone, surface sediment is greater than subsurface sediment in all river mile zones except RM 6 to 7, RM 8 to 9 and in Swan Island Lagoon. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles excpt RM 5 to 7 and RM 8 to 9. The subsurface sediment concentrations in the navigation channel are generally the same as the surface sediment concentrations, although the subsurface sediment concentrations are slightly greater in all river miles except RM 1.9 to 3 and RM 4 to 7.

Areas where subsurface sediment concentrations are elevated align with the locations where surface sediment concentrations are elevated, although there are more areas with elevated surface or subsurface sediment concentrations. The most prominent areas are RM 5 to 6, Swan Island Lagoon, and RM 11 to 11.8 in the eastern nearshore zone, and RM 8 to 11 in the western nearshore zones (Figure 5.2-47).

The surface sediment concentrations in the downstream reach were about the same as the subsurface concentrations. Both the mean surface and subsurface concentrations are 26 mg/kg (Tables 5.2-19 and 5.2-20)

5.2.11.5 Copper Sediment Relationship by River Reach

Comparisons of the copper data sets between the river reaches (Upriver, Downtown, Study Area, and Downstream) are discussed using the summary statistics and box-whisker plots.

Surface Sediment

There were far more data points in the Study Area reach (1,552) than in the other river reaches (Upriver – 72; Downtown – 269; Downtown excluding Zidell – 159; and Downstream – 25) which may affect the comparability of the data sets.

The Study Area reach has the highest median of 39 J mg/kg (Table 5.2-1) followed by the Downstream reach and Downtown reach medians of 27 mg/kg (Tables 5.2-19 and 5.2-15a), the Upriver reach meadian of 25 mg/kg (Table 5.2-11), and the Downtown reach excluding Zidell median of 24 mg/kg (Table 5.2-15b). These tables also show that the means of the data sets result in a different order of the reaches: Downtown reach (99 mg/kg); Study Area reach (61 mg/kg); Downtown reach excluding Zidell (33 mg/kg); Downstream reach (29 mg/kg); and Upriver reach (25 mg/kg).

A box-whisker plot showing the relationship of copper in sediment between the river reaches is presented in Figure 5.2-48. The box-whisker plots were plotted using both detet and nondetect data. The whiskers on the low end are indicative of the detection limits.

The relative dispersion of the Upriver data set and the Downstream data set are comparatively small. The length of the inner quartile for the Study Area and Downtown reaches are small compared to the whiskers, sugguestion a middle clustering of data about the median with a long upper whisker, representing a large dispersion of the relative data in the upper range of the data set. The long lower whisker for the Downtown reach is representative of the much lower detections used in this reach. The Downstream and Upstream data sets exhibit upward skewness while the Downtown reach exhibits downward skewness.

Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap in the Downstream and Study Area data sets, followed by the Upriver and Study Area, Downtown excluding Zidell and Study Area, Downtown excluding Zidell and Downstream, Downtown and Study Area, Downtown and Downstream, Upriver and Downtown, Downtown excluding Zidell and Downtown, Downtown excluding Zidell and Downstream, Upriver and Downtown excluding Zidell, and Upriver and Downstream. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and median of the Upriver reach overlaps with the spread and median of the Downtown data set; hence, there is no difference between these two data sets. Likewise, the spread and median of the Upriver and Downstream reaches, Upriver and Downtown excluding Zidell reaches, Downtown and Downtown excluding Zidell, Downtown excluding Zidell and Downstream reaches, and Downtown and Downstream reaches overlap so there is no difference between those data sets. The spead of the Downtown excluding Zidell reach overlaps the spread of the Study Area reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Study Area is greater than the data points collected Downtown excluding Zidell. This is also observed between the Downtown reach and the Study Area reach indicating that the majority of the data in the Study Area reach is greater than the data points collected in the Downtown reach. The spread and median of the Upriver reach and Study Area reach and Downstream and Study Area do not overlap indicating that the majority of the data in the Study Area reach is greater than the data points collected in the Upriver reach and the Downstream reach.

Subsurface Sediment

The Upriver subsurface data set is comprised of only three nondetected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like the surface sediment, the Study Area reach has far more data points (1,541) than the other reaches (Downtown – 178; Downtown excluding Zidell – 148; and Downstream – 26) which may have an effect on the comparison of the data sets.

The Study Area reach has the highest median of 36 mg/kg (Table 5.2-2), followed by the Downtown reach median and the Downtown reach excluding Zidell medians of 31 mg/kg (Tables 5.2-16a and b), and the the Downstream reach median of 27 mg/kg (Table 5.2-20). These tables also show the means of the data set result in a similar order of reaches: Study Area reach (55 mg/kg) and Downstream reach (26 mg/kg), Downtown reach (46 mg/kg), and Downtown reach excluding Zidell (39 mg/kg).

A box-whisker plot (Figure 5.2-48) showing the relationship of copper in sediment between the river reaches were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the Downstream data set is comparatively small. The length of the inner quartile for the Study Area and Downtown reaches is small compared to the whiskers, suggesting a middle clustering of data about the median. The long upper whisker of the Study Area reach represents a large dispersion of the relative data in the upper range of the data set. The Downtown and Downtown excluding Zidell data sets exhibit this to a lesser extent. The Downstream data sets exhibits upward skewness.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downstream and Study Area data sets, followed by the Downtown and Downstream data sets, the Downtown excluding Zidell and Downstream data sets, the Downtown excluding Zidell and Study Area data sets, the Study Area and Downtown data sets, and the Downtown exceluding Zidell and Downtown data sets. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of the Downtown reach and the Downtown reach excluding Zidell overlap each other; hence there is no difference between these data sets. This is also observed between the Study Area and Downtown and between the Study Area and Downtown excluding Zidell data sets. The spead of the Downtown reach overlaps the spread of the Downstream reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Downtown reach are greater than the data points collected in the Downstream reach. This is also observed between the Downtown excuding Zidel and Downstream data sets and between the Study Area and Downstream data sets.

~~5.13.20.15~~5.2.12 Zinc in Sediment

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Several data presentations for the surface and subsurface zinc data set within the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface concentrations by river mile. The distribution of zinc concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-31; concentrations with depth at subsurface stations are depicted on Maps 5.2-32a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-49 and 5.2-50 present scatter plots of the zinc data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-33).

The summary statistics for zinc in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respecteively. Tables 5.2-9 and 5.2-10 present zinc data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detected and nondetect values. Finally, a histogram presenting the average surface and subsurface sediment values by river mile and for the entire Study Area is in Figure 5.2-51.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-48. Summary statistics for surface and subsurface sediment within the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment within the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally, a box-whisker plot comparing the data sets for the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.2-52.

5.2.12.1 Zinc Data Set

The Study Area data set of zinc concentrations includes 1,581 surface samples and 1,581 subsurface samples. The Upriver data set includes 72 surface samples and 3 subsurface samples. The downtown data set includes 269 surface samples and 178 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples.

5.2.12.2 Zinc in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Zinc was analyzed and detected in 72 surface sediment samples within the Upriver reach (detection frequency of 100 percent), with detected concentrations ranging from 41 J mg/kg to 165 mg/kg (Table 5.2-11). Table 5.2-13 shows that four detected samples were greater than 100 mg/kg and the remaining 68 data points are between 10 and 100 mg/kg. The mean zinc concentration in this reach is 75 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Zinc was analyzed and detected in 269 surface sediment samples within the Downtown reach (detection frequency of 100 percent), with detected concentrations ranging from

3.3 J mg/kg to 6,480 J mg/kg (Table 5.2-15a) and a mean concentration of 294 mg/kg. The zinc concentrations in surface sediment varied along the Downtown reach (Map 5.2-48). The map shows that the majority of the samples are less than 300 mg/kg in this reach and that there are clusters of samples with concentrations greater than 600 mg/kg at RM 13 on the western shore under the Hawthorn Bridge and on the western shore between the Marquam and Ross Island bridges.

Table 5.2-17 and 5.2-18 shows that there are 15 samples (6 percent of data set) greater than 1,000 mg/kg. Another 102 samples (38 percent of the data set), are detected at concentrations ranging from 100 to 1,000 mg/kg. Over half of the data, 151 samples or 56 percent of the data set, is detected at concentrations ranging between 10 and 100 mg/kg. The remaining sample is at concentrations less than 10 mg/kg. There are no samples detected at concentrations less than 1 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Zinc was analyzed and detected in 110 surface sediment samples within the Zidell action area with concentrations ranging from 3.27 J mg/kg to 6,480 J mg/kg (Table 5.2-15c). The mean zinc concentration for this area is 555 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15b), the range of zinc concentrations in surface sediment is from 23 mg/kg to 1,450 mg/kg with a mean concentration of 113 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Zinc was analyzed and detected in 1,581 surface sediment samples within the Study Area (detection frequency of 100 percent) with concentrations ranging from 3.7 J mg/kg to 4,220 mg/kg (Table 5.2-1). The mean Inc concentration of surface sediment in the Study Area is 154 mg/kg. Zinc concentrations in surface sediment varied along the Study Area (Figure 5.2-49).

Four prominent peaks (greater than 300 mg/kg) in the surface sediment are identified in the eastern nearshore zone (Figure 5.2-49). Clusters of concentrations greater than 300 mg/kg occur at RM 2.1-2.3, RM 3.7-4.6, RM 5.6-5.9, and in Swan Island Lagoon (Figure 5.2-45 and Map 5.2-29). A single exceedance of concentrations greater than 300 mg/kg is noted at RM 6.7, RM 7.2, RM 9.9, and 11.3. A surface sample at RM 4.6 (Station T4-UP13) contained the highest concentration of zinc (2,050 mg/kg) in the eastern nearshore zone. Mean zinc concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 190 mg/kg for RM 1.9 to 3; 159 mg/kg for RM 3 to 4; 234 mg/kg for RM 4 to 5; 192 mg/kg for RM 5 to 6; 123 mg/kg for RM 6 to 7; 114 mg/kg for RM 7 to 8; 227 mg/kg in Swan Island Lagoon; 97.1 mg/kg for RM 9-10; and 132 mg/kg for RM 11 to 11.8.

The western nearshore zone has detected zinc concentrations that exceed 300 mg/kg from RM 6.1 through 10.4. It appears that five prominent peaks (clusters of concentrations greater than 300 mg/kg) are located at RM 6.1, RM 6.7-6.8, RM 8.1-9.3, RM 9.6-9.7, and RM 10.3-10.4 (Figure 5.2-49. The maximum surface concentration in the Study Area (4,220 mg/kg) was found in western nearshore zone at Station HA-43 (RM 9.2W). Mean concentrations (Table 5.2-7) for these areas in the western nearshore zone are: 150 mg/kg for RM 6 to 7; 290 mg/kg for RM 8 to 9; 394 mg/kg for RM 9 to 10; and 212 mg/kg for RM 10 to 11. There were no samples exceeding 300 mg/kg zinc in the navigation channel.

Table 5.2-9 shows that there are 15 samples exceeding 1,000 mg/kg. Another 914 detected data points in surface sediment greater than 100 mg/kg. Surface sediment values greater than 100 mg/kg accounts for over half (59 percent) of the detected data set. An additional 650 samples (41 percent of the detected data set) were detected at concentrations between 10 and 100 mg/kg. The remaining two surface sediment samples were detected at concentrations less than 10 mg/kg. There were no samples were detected at concentrations less than 1 mg/kg.

Downstream Reach (RM 0 to 1.9)

Zinc was analyzed and detected in 25 surface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 48 mg/kg to 188 mg/kg (Table 5.2-19). Table 5.2-21 shows that 12 samples are measured at concentrations greater than 100 mg/kg and 13 samples are measured at concentration less than 100 mg/kg. There were no samples were detected at concentrations less than 10 mg/kg. The mean zinc concentration in this reach is 98 mg/kg.

5.2.12.3 Zinc in Subsurface Sediment

Upriver Reach (RM 15.3 to 26)

Zinc concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 66 mg/kg to 119 mg/kg; the average concentration for this reach is 88 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Zinc was analyzed and detected in 178 subsurface sediment samples within the Downtown reach (detection frequesncy of 100 percent), with concentrations ranging from 21 mg/kg to 11,100 J mg/kg (Table 5.2-16a) and a mean concentration of 379 mg/kg. Table 5.2-17 shows that only one sample was detected at a concentration greater than 10,000 mg/kg and nine samples were detected at concentrations between 1,000 and 10,000 mg/kg. Another 77 samples were detected at concentrations between 100 and 1,000 mg/kg. Subsurface sediment values greater than 100 mg/kg account for 49 percent of the detected data set. Half of the data set (91 samples; 51 percent of the detected data set) is detected at concentrations between 10 and 100 mg/kg. There were no samples were detected at concentrations less than 10 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the Downtown data set. Zinc was analyzed in 30 subsurface sediment samples within the Zidell action area with concentrations ranging from 41 mg/kg to 2,270 mg/kg. The mean zinc concentration for this area is 207 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-16c), the range of zinc concentrations in subsurface sediment is from 21 mg/kg to 11,100 J mg/kg with a mean concentration of 414 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Zinc was analyzed and detected in 1,581 samples within the Study Area (100 percent detection frequency) with concentrations ranging from an 24 mg/kg to 9,000 mg/kg (Table 5.2-2) and a mean concentration of 147 mg/kg. Similar to surface sediment, zinc concentrations in the subsurface also varied within the Study Area (Figure 5.2-50; Maps 5.2-32a-o).

The subsurface sediment has elevated concentrations in generally the same areeas identified in the surface sediment within the eastern nearshore zone (Figure 5.2-50). Concentrations greater than 300 mg/kg are noted at RM 2.3, 3.7, RM 4.2-4.6, RM 5.6, RM 6.7, in Swan Island Lagoon, RM 8.4-8.6, and RM 11.1 (Figure 5.2-51 and Map 5.2-32a-o). The maximum subsurface zinc concentration in the eastern nearshore zone (1,930 mg/kg) was found at Station C384 (30–128 cm bml), at the mouth of Swan Island Lagoon. Mean zinc concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are: 131 mg/kg for RM 1.9 to 3; 149 mg/kg for RM 3 to 4; 155 mg/kg for RM 4 to 5; 171 mg/kg for RM 5 to 6; 133 mg/kg for RM 6 to 7; 291 mg/kg for RM 8 to 9; 181 mg/kg in Swan Island Lagoon, and 159 mg/kg for RM 11 to 11.8.

The western nearshore zone has detected zinc concentrations that exceed 300 mg/kg from RM 6.7 through 9.2 with clusters noted at RM 6.7, RM 7.6-7.7, and RM 8.3-9.2 (Figure 5.2-50 and Map 5.2-32a-o). The maximum subsurface concentration (9,000 mg/kg) was found at Station HA-42 (46–61 cm bml) at RM 8.9. Mean concentrations (Table 5.2-8) for these areas in the western nearshore zone are: 126 mg/kg for RM 6 to 7; 131 mg/kg for RM 7 to 8; 190 mg/kg for RM 8 to 9; and 792 mg/kg for RM 9 to 10.

There is one peak with samples greater than 300 mg/kg in the navigation channel zone located at RM 10.2-10.3 with two indivial samples exceeding 300 mg/kg at RM 6.4 and RM 7.9. The concentrations elevated within the navigation channel are near elevated concentrations the western nearshore zone. The mean concentrations for these areas are: 102 mg/kg for RM 6 to 7; 125 mg/kg for RM 7 to 8; and 127 mg/kg for RM 10 to 11 (Table 5.2-6).

Table 5.2-9 shows that there are 6 subsurface samples greater than 1,000 mg/kg and 834 samples ranging between 100 and 1,000 mg/kg. Subsurface sediment values greater than 100 mg/kg accounts for 53 percent of the detected data set. The remainder of the detected data set (741 samples; 47 percent) is between 10 and 100 mg/kg. There were no samples detected at concentrations less than 10 mg/kg.

Downstream Reach (RM 0 to 1.9)

Zinc was analyzed and detected in 26 subsurface sediment samples within the Downstream reach (detection frequency of 100 percent), with concentrations ranging from 11 mg/kg to 244 mg/kg (Table 5.2-20). Table 5.2-21 shows that approximately half of samples (14 samples) were detected at a concentration greater than 100 mg/kg and half the samples (12 samples) were detected at a concentration less than 100 mg/kg. There were no samples were detected at concentrations less than 10 mg/kg. The mean zinc concentration in this reach is 118 mg/kg.

5.2.12.4 Zinc Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver reach. However, due to the geologic structure, it is unlikely that there would be subsurface sediment contamination. The mean zinc surface sediment concentration in this reach is 75 mg/kg (Table 5.2-11).

The surface sediment concentrations in the downtown reach were lower than the subsurface concentrations. The mean surface concentration is 294 mg/kg, while the mean subsurface sediment concentration is 379 mg/kg (Tables 5.2-15a and 5.2-16a).

Zinc concentrations are generally greater in the surface sediments than in subsurface sediments within the Study Area as a whole. The mean surface sediment concentration is 154 mg/kg and the mean subsurface sediment concentration is 147 mg/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-51 shows that mean concentrations are greater in the nearshore areas than in the navigation channel and the western nearshore zone has slightly greater subsurface concentrations than the eastern nearshore zone while the eastern nearshore zone has higher surface concentration. It also shows that concentrations are generally about the same in the surface sediment and subsurface sediment.

In the eastern nearshore zone, surface sediment is greater than subsurface sediment in all river mile zones except RM 6 to 9 and RM 10 to 11.8. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles excpt RM 3 to 4, RM 6 to 7 and RM 8 to 9. The subsurface sediment concentrations in the navigation channel are generally the same as the surface sediment concentrations, although the subsurface sediment concentrations are slightly greater in all river miles except RM 5 to 6.

Areas where subsurface sediment concentrations are elevated generally align with the locations where surface sediment concentrations are elevated, although there are more areas with elevated subsurface sediment concentrations. The most prominent areas are RM 4 to 5, in Swan Island Lagoon, and RM 8 to 9 in the eastern nearshore zone, and RM 8 to 10 in the western nearshore zones. Additional areas with elevated concentrations are RM 1.9 to 3 and RM 5 to 6 in the eastern nearshore zone, and RM 10 to 11 in the western nearshore zone (Figure 5.2-51).

The subsurface sediment concentrations in the downstream reach were greater than surface concentrations. The mean surface concentration is 98 mg/kg, while the mean subsurface concentration is 118 mg/kg (Tables 5.2-19 and 5.2-20)

5.2.12.5 Zinc Sediment Relationship by River Reach

Comparisons of the zinc data sets between the river reaches (Upriver, Downtown, Study Area, and Downstream) are discussed using the summary statistics and box-whisker plots.

Surface Sediment

There were far more data points in the Study Area reach (1,581) than in the other river reaches (Upriver – 72; Downtown – 269; Downtown excluding Zidell – 159; and Downstream – 25) which may affect the comparability of the data sets.

The Study Area reach has the highest median of 106 J mg/kg (Table 5.2-1) followed by the Downstream reach median of 100 mg/kg (Table 5.2-19), the Downtown reach median of 91 mg/kg (Table 5.2-15a), the Downtown reach excluding Zidell median of 78 J mg/kg (Table 5.2-15b), and the Upriver reach meadian of 75 mg/kg (Table 5.2-11). These tables also show that the means of the data sets result in a different order of the reaches: Downtown reach (294 mg/kg); Study Area reach (154 mg/kg); Downtown reach excluding Zidell (113 mg/kg); Downstream reach (98 mg/kg); and Upriver reach (75 mg/kg).

A box-whisker plot showing the relationship of zinc in sediment between the river reaches is presented in Figure 5.2-52. The box-whisker plots were plotted using both detet and nondetect data. The relative dispersion of the Upriver data set and the Downstream data set are comparatively small. The length of the inner quartile for the Study Area and Downtown reaches are small compared to the whiskers, sugguestion a middle clustering of data about the median with a long upper whisker, representing a large dispersion of the relative data in the upper range of the data set. The Downstream and Upstream data sets exhibit upward skewness while the Downtown and Study Area reaches exhibit~~s~~ downward skewness.

Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap in the Upriver and Study Area data sets, followed by the Upriver and Downtown, Upriver and Downstream, Downtown excluding Zidell and Study Area, Study Area and Downstream, Downtown excluding Zidell and Downtown, Downtown excluding Zidell and Downstream, Downtown and Study Area, Downtown and Downstream, and Upriver and Downtown excluding Zidell. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and median of the Upriver reach and Study Area reach do not overlap indicating that the majority of the data in the Study Area reach is greater than the data points collected in the Upriver reach. The spead of the Upriver reach overlaps the spread of the Downtown reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data in the Downtown reach is greater than the data points collected in the Upriver reach. This is also observed between the Upriver reach and the Downstream reach indicating that the majority of the data in the Downstream reach is greater than the data points collected in the Upriver reach. The spread and medians of all other data set pairs overlap; hence, there is no difference between any remaining data set pairs.

Subsurface Sediment

The Upriver subsurface data set is comprised of only three nondetected values; thus, there is not enough data upriver to draw meaningful conclusions between this reach and the other reaches. Like the surface sediment, the Study Area reach has far more data points (1,581) than the other reaches (Downtown – 178; Downtown excluding Zidell – 148; and Downstream – 26) which may have an effect on the comparison of the data sets.

The Downstream reach has the highest median of 125 mg/kg (Table 5.2-20), followed by the Study Area reach median of 105 J mg/kg (Table 5.2-2), the Downtown reach median of 99 J mg/kg (Table 5.2-16a), and the Downtown reach excluding Zidell median~~s~~ of 96 mg/kg (Tables 5.2-16b). These tables also show the means of the data set result in a different order of reaches: Downtown reach excluding Zidell (414 mg/kg), Downstream reach (379 mg/kg), Study Area reach (147 mg/kg), and Downstream reach (118 mg/kg).

A box-whisker plot (Figure 5.2-52) showing the relationship of zinc in sediment between the river reaches were plotted using both detect and nondetect data. The relative dispersion of the Downstream data set is comparatively small. The length of the inner quartile for the Study Area and Downtown reaches is small compared to the whiskers, suggesting a middle clustering of data about the median. The long upper whisker of the Study Area and Downtown reaches represents a large dispersion of the relative data in the upper range of the data set. The Downtown excluding Zidell data sets exhibit this to a lesser extent. The long lower whisker of the Downstream reach represents a large dispersion of the relative data in the lower range of the data set. The Downstream data sets exhibits downward skewness while the other reaches exhibit slight upward skewness.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. Visually, the data sets all seem to overlap. Whether or not these similarities in the data sets are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) and medians of all the data set pairs overlap; hence, there is no difference between any data set pairs.~~Zinc was found at concentrations greater than 200 mg/kg (Maps 5.1-25 and 5.1-26a–m, see frequency plot inset) at many locations along the eastern and western nearshore zones, but few in the navigation channel. Detection frequencies were 100 percent for both surface and subsurface samples (Figures 5.1-29 and 5.1-30; Tables 5.1-1 and 5.1-2). Where the latter elevations appeared, extent was generally limited (Maps 5.1-25 and 5.1-26a–m). Ninety-five percent of the surface samples were below 375 V mg/kg.~~

~~The highest surface (HA-43) and subsurface (HA-42; 46–61 cm bml) concentrations were found between RM 8.2 and 9.2. Station HA-42 also recorded the highest chromium concentration in the Study Area.~~

~~5.13.20.16~~5.2.13 Tributyltin Ion in Sediment

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Several data presentations for the surface and subsurface tributyltin ion data sets for the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface sediment concentrations by river mile. The distribution of tributyltin ion concentrations at each surface sampling station throughout the Study Area is depicted in Map 5.2-33; concentrations with depth at subsurface stations are depicted in Maps 5.2-34a–o.

The complete data set for tributyltin ion surface and subsurface sediment concentrations in the study area is plotted on scatter plots presented in Figures 5.2-53 and 5.2-54. The scatter plots present the data in three panels segregated by the eastern nearshore, navigation channel, and western nearshore zones (Map 5.2-33).

The summary statistics tributyltin ion in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the tributyltin ion data as orders of magnitude (e.g., <1, 1-10, 10-100, 100-1,000, etc.) for only detected values and for combined detect and nondetect values. Finally a histogram presenting the average surface and subsurface sediment values for tributyltin ion by river mile and for the entire Study Area is presented in Figure 5.2-59.

Data sets for the Upriver reach, Downtown reach, and Downstream reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown reach surface sediment samples are presented in Map 5.2-49. Summary statistics for surface and subsurface sediment within the the Upriver reach are shown in Tables 5.2-11 and 5.2-12; number of data points by order of magnitude are provided in

Tables 5.2-13 (detect only) and 5.2-14 (detect and nondetect). Summary statistics for surface and subsurface sediemtn within the Downtown reach are shown in Tables 5.2-15 and 5.2-16; number of data points by order of magnitude are provided in tables 5.2-17 (detect only) and 5.2-18 (detect and nondetect). Summary statistics for surface and subsurface sediment with the Downstream reach are shown in Tables 5.2-19 and 5.2-20; number of data points by order of magnitude are provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and nondetect). Additionally a box-whisker plot comparing the data sets for tributyltin ion in the Upriver reach, Downtown reach, Study Area reach, and Downstream reach is presented in Figure 5.256.

5.2.13.1 Tributyltin Ion Data Set

The number of sediment samples for tributyltin ion analysis was typically based on a highly biased approach at locations near known or suspected sources. As a result, there are relatively fewer data points for these analytes in the RI sediment database than for other chemicals (for example, the tributyltin data set is approximately one-fifth the size of the PCBs and DDx data sets). This is particularly true in areas away from suspected sources, such as the navigation channel.

The existing tributyltin ion data are sufficient for RI purposes; however, as will be pointed out in this section and later in Section 10, the fewer number of data points for tributyltin ion in some areas limits the level of detail to which the extent of chemical distribution may be resolved, and introduces the need for caution in interpreting the surface to subsurface trends shown by the histograms (Figures 5.2-59) and in making conclusions regarding the spatial patterns of the composition of tributyltin ion in sediment (Sections 5.2.13.2 and 5.2.13.3). Tributyltin ion data for sediment within the Study Area are available for 358 surface and 433 subsurface samples. The Upriver data set includes 8 surface samples and 3 subsurface samples. The downtown data set includes 174 surface samples and 65 subsurface samples. The downstream data set includes 4 surface samples and no subsurface samples.

5.2.13.2 Tributyltin Ion in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Tributyltin ion was analyzed in 8 surface sediment samples and detected in 4 samples within the Upriver reach (detection frequency of 50 percent), with detected concentrations ranging from 0.72 J ug/kg to 2.3 ug/kg (Table 5.2-11). Tables 5.2-13 shows that there are 3 detected data points between 1 and 10 ug/kg and one data point detected at a concentration less than 1 ug/kg. The mean tributyltin ion concentration in this reach is 1.3 ug/kg.

Downtown Reach (RM 11.8 to 15.3)

Tributyltin ion was analyzed in174 surface sediment samples and detected in 62 samples within the Downtown reach (detection frequency of 36 percent), with detected concentrations ranging from 0.4 J ug/kg to 1,990 ug/kg (Table 5.2-15a) and a mean concentration of 75 ug/kg. Tributyltin ion concentrations in surface sediment varied along the Downtown reach (Map 5.2-49). The map shows that the majority of the samples with highest concentrations are located along the western shoreline.

Tables 5.2-17 shows that there are two detected data points greater than 1,000 ug/kg. There are also two detected values between 100 and 1,000 ug/kg. An addional 12 samples, 19 percent of the detected data set, were detected at concentrations between 10 and 100 ug/kg. Over half the samples, 32 samples or 52 percent of the detected data set, were detected at concentrations ranging between 1 and 10 ug/kg. Another14 samples, or 23 percent of the detected data set, are detected at a concentration less than 1 ug/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-15b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-15c presents the data statistics for the Zidell data removed from the Downtown data set. Tributyltin ion was analyzed in 80 surface sediment samples and detected in 26 samples within the Zidell action area with concentrations ranging from 1.9 ug/kg to 1,990 ug/kg (Table 5.2-15c). The mean tributyltin ion concentration for this area is 102 ug/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15b), the range of tributyltin concentrations in surface sediment is from 0.4 J ug/kg to 1,700 J ug/kg with a mean concentration of 55 ug/kg.

Study Area Reach (RM 1.9 to 11.8)

Tributyltin ion was analyzed in 358 surface sediment samples and detected in 333 samples (detection frequency of 93 percent). Surface concentrations ranged from 0.45 J ug/kg to 47,000 ug/kg (Table 5.2-1), with a mean concentration of 466 ug/kg. Tributyltin ion concentrations in surface sediment varied along the Study Area (Figure 5.2-49). Tributyltin ion concentrations exceeding 1,000 ug/kg in the scatter plots are indicated in orange and red on Map 5.2-33.

The eastern nearshore zone has only one promenant peak with concentrations exceeding 1,000 ug/kg in Swan Island Lagoon; a single measurement exceeding 1,000 ug/kg is located at RM 3.7 (head of International Slip). Mean concentrations (see Table 5.2-3) for these areas in the eastern nearshore zone are: 1,570 ug/kg for RM 3 to 4 and 2,340 ug/kg for Swan Island Lagoon.

There is also a single measurement exceeding 1,000 pg/g in the western nearshore zone at RM 8.8. Mean concentrations (see Table 5.2-7) for this area in the western nearshore zone is 84 ug/kg for RM 8 to 9. The highest surface sediment concentration (47,000 ug/kg) in the data set was in the sample at the head of International Slip (SD12). The highest sample collected at Swan Island Lagoon was 46,000 ug/kg (G421).

There was one prominent peak in the navigation channel zone located adjacent to Swan Island Lagoon (Figure 5.2-49). The maximum concentrations in this area is 1,800 ug/kg

(SD124) at RM 7.7. The associated mean concentration for this areas is: 373 ug/kg for RM 7 to 8 (Table 5.2-5).

Tables 5.2-9 shows that there are only 2 data points greater than 10,000 ug/kg. There are 12 detected values between 1,000 and 10,000 ug/kg, which are within the prominent peaks described above. Surface sediment concentrations greater than 1,000 ug/kg accounts for four perent of the detected data set (Map 5.2-33). There are 71 samples (21 percent of the detected data set) detected at concentrations ranging between 100 and 1,000 ug/kg. Over a third of the detected data set (125 samples; 38 percent) is comprised of samples ranging from 10 to 100 ug/kg. Another 108 samples, or 32 percent, are detected at concentrations between 1 and 10 ug/kg and 15 samples, or less than one percent, were detected at concentrations less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

Tributyltin ion was analyzed and detected in all 4 samples within the Downstream reach, with concentrations ranging from 0.37 J ug/kg to 1.2 J ug/kg (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there are two data points with concentrations ranging between 1 and 10 ug/kg and two samples detected at concentrations less than 1 ug/kg. The mean tributyltin ion concentration in this reach is 0.85 ug/kg.

5.2.13.3 Tributyltin Ion in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Tributyltin ion was analyzed in three subsurface sediment samples between RM 15.4 and 16 and was not detected any samples within the Upriver reach. The maximum detect level for tributyltin ion was 0.094 U ug/kg.

Downtown Reach (RM 11.8 to 15.3)

Tributyltin ion was analyzed in 65 subsurface sediment samples and detected in 21 samples within the Downtown reach (detection frequency of 32 percent), with detected concentrations ranging from 0.55 J ug/kg to 14,000 ug/kg (Table 5.2-15a) and a mean concentration of 1,052 ug/kg.

Tables 5.2-17 show that there is one detected value greater than 10,000 ug/kg and one value detected between 1,000 and 10,000 ug/kg. An additional sample was detected at a concentration between 100 and 1,000 ug/kg. Another five samples, 24 percent of the detected data set, were detected at concentrations ranging between 10 and 100 ug/kg. Almost half of this data set, 9 samples or 8 percent of the detected data set, are between 1 and 10 ug/kg and four samples were detected at a concentration less than 1 ug/kg.

In 2011, a remedial action was taken at the Zidell facility under ODEQ authority. Table 5.2-16b presents the data statistics for the Downtown reach excluding the Zidell data and Table 5.2-16c presents the data statistics for the Zidell data removed from the

Downtown data set. Tributyltin ion was analyzed in 23 subsurface sediment samples within the Zidell action area with concentrations ranging from 0.0015 U ug/kg to 14,000 ug/kg. The mean tributyltin ion concentration for this area is 1,697 ug/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-16c), the range of tributyltin ion concentrations in subsurface sediment ranges from 0.55 J ug/kg to 23 ug/kg with a mean concentration of 4.5 ug/kg.

Study Area Reach (RM 1.9 to 11.8)

Tributyltin ion was detected in 223 of the 433 subsurface samples analyzed within the Study Area (detection frequency of 52 percent), with concentrations ranging from 0.32 J ug/kg to 90,000 ug/kg and a mean concentration of 1,410 ug/kg (Table 5.2-2). Similar to surface sediment, tributyltin ion concentrations in the subsurface also varied within the Study Area (Figure 5.2-50; Maps 5.2-34a-o).

The greatest tributyltin ion concentrations (1,000 ug/kg) are seen in Swan Island Lagoon and extending downstream in the eastern nearshore zone through RM 7 (Figure 5.2-50). A single sample with a concentration of 1,000 ug/kg is noted at RM 5.6. Mean concentration (see Table 5.2-4) for these areas in the eastern nearshore zone are: 196 ug/kg for RM 5 to 6; 1,250 ug/kg for RM 7 to 8; 13,700 ug/kg for RM 8 to 9; and 5,380 ug/kg in Swan Island Lagoon.

There are no areas in the western nearshore zone that exceed 1,000 ug/kg (Figure 5.2-50). Limited subsurface tributyltin ion data are available for the navigation channel; of the samples that were analyzed, most concentrations were less than 100 ug/kg. Concentration greater than 1,000 ug/kg are only seen in the navigation channel near Swan Island Lagoon spreading downstream to RM 8 (Maps 5.2-34a-o). Elevated concentrations in the subsurface samples are generally found at the same surface locations with tributyltin ion concentrations greater than 1,000 ug/kg along the eastern nearshore zone (Maps 5.2-34a–o).

Table 5.2-9 shows that there are only eight data points greater than 10,000 ug/kg. There are 14 detected values between 1,000 and 10,000 ug/kg, which are within the elevated concentration areas described above. Subsurface sediment concentrations greater than 1,000 ug/kg account for about one perent of the detected data set. An additional 35 samples (16 percent of the detected data set) is comprised of samples ranging from 100 to 1,000 ug/kg. Another 88 samples, or 39 percent, are detected at concentrations between 10 and 100 ug/kg. There were 62 samples, or 28 percent, were detected at concentrations ranging from 1 to 10 ug/kg and 16 samples, or less than one percent, were detected at concentrations less than 1 ug/kg.

Downstream Reach (RM 0 to 1.9)

Tributyltin ion was not analyzed in subsurface sediment within the Downstream reach.

5.2.13.4 Tributyltin Ion Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area reach. There is insufficient data to compare surface and subsurface concentrations in the Upriver and Downstream reaches. However, due to the geologic structure of the upriver reach, it is unlikely that there would be subsurface sediment contamination.

The subsurface tributyltin ion sediment concentrations in the downtown reach are higher than the surface concentrations. The mean surface tributyltin ion concentration is 75 ug/kg and the subsurface concentration is 1,052 ug/kg. With the Zidell data removed this relationship is inversed; the mean surface tributyltin ion concentrations is 55 ug/kg and the subsurface concentrations is 4.5 ug/kg.

Tributyltin ion concentrations are generally greater in the subsurface sediments than in surface sediments within the Study Area as a whole. The mean tributyltin ion surface sediment concentration is 466 ug/kg and the subsurface concentration is 1,410 ug/kg. Most areas throughout the Study Area reach lack a strong or consistent vertical concentration gradient, although the majority of the contamination appears in the shallower near-surface samples. This pattern may be due to the lack of samples and is supported by Maps 5.2-34d-j. This suggests a recient historical source or sources of tributyltin ion in the Study Area.

5.2.13.5 Tributyltin Ion Sediment Relationships by River Reach

Comparisons of the tributyltin ion data sets between the river reachs (Upriver, Downtown, Downtown exluding Zidell, Study Area and Downstream) are discussed in this section using the summary statistics tables and box-whisker plots.

Surface Sediment

There were far more data points in the Study Area reach (358), than in the other river reaches (Upriver – 8; Downtown – 174; and Downstream – 4) which may affect the comparability of the data sets.

The Study Area reach had the highest tributyltin median of 22 ug/kg (Table 5.2-1), followed by the Downtown reach median of 4.1 ug/kg (Table 5.2-15a), the Upriver reach median of 1.1 J ug/kg (Table 5.2-11), and the Downstream reach median of 0.92 J ug/kg (Table 5.2-19). These tables also show the means of the tributyltin ion data set results in the same order of the reaches: Study Area (466 ug/kg), Downtown reach (75 ug/kg); Upriver reach (1.3 ug/kg), and Downstream reach (0.85 ug/kg).

A box-whisker plot showing the relationship of tributyltin ion in sediment between the river reaches is presented in Figure 5.2-56. The box-whisker plots were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set. The relative dispersion of the Downstream and Upriver data sets is comparatively small. The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative data in the upper range of the data set. This is also seen in the Downtown data set. The Study Area reach exhibits downward skewness, while all the other reaches exhibit upward skewness.

Comparing the surface data sets from each reach, several inferences can be made about the underlying populations. There is visually the least overlap between the Downstream and Study Area data sets, followed by the Upriver and Study Area, Downtown and Study Area, Upriver and Downstream, and Upriver and Downtown. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

The spread (i.e., inner quartile) of the Upriver reach overlaps the spread of the Downstream reach; however, the median of the Upriver reach does not overlap the spread of the Downstream reaches. Thus, it is likely that the majority of the data points for the Downstream reach is greater than the data points collected Upriver. This is also true for the comparison of the Downtown reach and Downstream reach data. There is no overlap in the Upriver, Downtown or Downstream and Study Area spreads; consequently, the Study Area data set is greater than the other data sets. The spread and medians of the Upriver reach and the Downtown reach overlap each other; hence there is no difference between these two data sets.

Subsurface Sediment

The upriver subsurface data set is comprised of only three nondetected values and no samples were collected from the downstream reach; thus, there is not enough data upriver or downstream to draw meaningful conclusions between these reaches and the Downtown or Study Area reaches. Like the surface sediment, the Study Area reach has far more data points (433) than the Downtown reach (65) which may have an effect on the comparison of the data sets.

The Study Area reach had the highest median of 29 ug/kg (Table 5.2-2), followed by the Downtown reach median of 6 ug/kg (Table 5.2-16a). These tables also show the means of the data sets result in the same order of the reaches: Study Area reach (1,410 ug/kg) and Downtown reach (1,052 ug/kg).

A box-whisker plot showing the relationship of tributyltin ion in sediment between the river reaches is presented in Figure 5.2-12. The box-whisker plots were plotted using both detect and nondetect data. The whiskers on the low end are indicative of the detection limits for the data set.

The relative dispersion of the Upstream data set is comparatively small due to the small number of data points (i.e., three) that were all nondetect. The length of the inner quartile for the Study Area is small compared to the whiskers, suggesting a middle clustering of data about the median with a long upper whisker representing a large dispersion of the relative data in the upper range of the data set. This is also appearant in the Downtown data set. Like the surface sediment plots, the whiskers on the low end are indicative of the detection limits for the data set. However, the lower bound whisker on the Study Area and Downstream subsurface plots show that extremely low detection limits were used for these data set compared to the other data sets, which would tend to skew the data downward. This will result in the comparisons of other data sets to this one less reliable. Both the Study Area reach exhibits slight upward skewness, while the Downtown reach exhibits downward skewness.

Comparing the subsurface data sets from each reach, several inferences can be made about the underlying populations. There is visually overlap between the Downtown and Study Area data sets. The spread of the Downtown reach overlaps the spread of the Study Area reach; however, the medians do not overlap the spread. Thus, it is likely that the majority of the data points for the Study Area reach is greater than the data points collected in the Downtown reach. Whether or not these differences are statistically significant is partly a function of the sample size and ultimately requires significance testing.

~~Sediment samples at selected locations were analyzed for butyltins. Bulk sediment TBT concentrations varied among locations (Maps 5.1-27 and 5.1-28a–m; Figures 5.1-31 and 5.1-32). Frequencies of detection for TBT were 94 percent for surface samples and 59 percent for subsurface samples (Tables 5.1-1 and 5.1-2). Ninety-five percent of the surface samples were less than 851 V µg/kg.~~

~~Concentrations greater than 1,000 µg/kg (Maps 5.1-27 and 5.1-28a–m; see frequency plot inset) were measured in surface samples near the western nearshore zone at RM 9 and near the entrance to the International Terminals Slip. Most concentrations greater than 1,000 µg/kg were found near RM 8 in areas surrounding Swan Island and immediately downstream of Swan Island. The maximum surface concentration of TBT was found at the mouth of the International Terminals Slip (Station SD012). Station PSY30C (121–152 cm bml) at RM 8.2 near Swan Island contained the highest subsurface concentration of TBT in the Study Area.~~

~~5.13.21~~ ~~Summary of the Nature and Extent~~In-river Distribution ~~of Indicator Chemicals~~ Contaminants ~~in Sediment~~

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~~PCBs, PCDD/Fs, DDx, and PAHs were found across the Study Area, but concentrations varied by orders of magnitude. Concentrations of these chemicals were lowest in the navigation channel and highest in localized, generally well-defined, nearshore areas along both the west and east river banks.~~

~~The surface to subsurface mean concentration ratios indicated that PCBs were higher in the subsurface than surface in the Study Area as a whole. A notable exception was RM 11–11.8, where mean PCB concentrations were notably higher in the surface~~

~~sediment than in the subsurface sediment. In general, the overall chlorination level of PCBs in the surface and subsurface sediments in the eastern nearshore zone tended to be higher upriver in the Study Area and lower downstream. Homolog patterns in areas of high PCB concentration tended to be more variable in the western nearshore zone. These variances in the relative abundances of the homolog groups may reflect differences in the sources of the PCBs.~~

~~For PCDD/Fs, the surface to subsurface ratios were generally close to one, indicating that the surface and subsurface concentrations were comparable across the entire Study Area. Exceptions to this pattern occurred in the area under and just upstream of the Railroad Bridge at RM 6.9, where surface concentrations were higher, and in the northwest corner of Willbridge Terminal, where subsurface concentrations were higher. OCDD was the predominant homolog (>50 percent) in surface and subsurface sediment within the Study Area.~~

~~The surface to subsurface ratios for DDx within the Study Area indicated that concentrations were higher in the subsurface than in the surface layer. Along the west bank from RM 7 to 8, where total DDx levels were highly elevated, the average subsurface concentration greatly exceeded the overall surface concentrations. The 4,4'-isomer of DDT dominated the surface sediment profile here, while DDT and DDD dominated the subsurface profile, possibly indicating degradation of DDT to DDD in the deeper anoxic sediments. Overall, the 4,4'-isomers were more abundant than the 2,4'-isomers within the Study Area.~~

~~The surface to subsurface ratios for PAHs indicated that concentrations were higher in the subsurface than in surface sediments. A notable exception occurs at RM 5–6 where the mean channel surface concentration was considerably higher than the mean subsurface concentration. The proportions of individual PAHs varied throughout the Study Area, possibly reflecting PAH contributions from multiple sources, as well as weathering and degradation. Three-ring LPAHs and four-ring HPAHs dominated the western shoreline profile between RM 5.4 and 6.6 where the highest PAH concentrations were found.~~